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SIZE	CODE IDENT NO.	DRAWING NO.
A	29562	ICD-GPS-200
SCALE:	REV: B-PR	SHEET: 1 OF 115

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ICD-GPS-200B-PR Navstar GPS Space Segment/Navigation User Interfaces (Public Release Version)

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ICD-GPS-200B-PR

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This Interface Control Document (ICD) defines the functional characteristics required to exist to assure compatibility between the Space Segment (SS) of the Global Positioning System and the Navigation User Segment (US) of the GPS. The exception is that this ICD does not define characteristics of the Selective Availability or Anti-Spoofing features, which are not available to the general public.

Global Positioning System, GPS, ICD-GPS-200

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IRN-200B-PR-001
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REVISION RECORD

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INTERFACE CONTROL DOCUMENT

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SCALE: | REV: B-PR | SHEET: iii OF 115

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Pages	Revision
i-ii	IRN-200B-PR-001
iii-iv	Original
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11-38	Original
39-42	IRN-200B-PR-001
43-64	Original
65-68b	IRN-200B-PR-001
69-72	Original
73-74	IRN-200B-PR-001
75-78	Original
79-80	IRN-200B-PR-001
81-82	Original
83-84	IRN-200B-PR-001
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85-86	IRN-200B-PR-001
87-88	Original
89-90	IRN-200B-PR-001
91-108b	Original
109-110b	IRN-200B-PR-001
111-115	Original

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

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1. SCOPE

1.1 Scope. This Interface Control Document (ICD) defines the functional characteristics required to exist to assure compatibility between the Space Segment (SS) of the Global Positioning System (GPS) and the Navigation User Segment (US) of the GPS. The exception is that this ICD does not define characteristics of the Selective Availability or Anti-Spoofing features, which are not available to the general public.

1.2 Key Dates. The major milestones for which integration data shall be provided are:

a. (TBD)

1.3 ICD Approval and Changes. (SECTION REMOVED)

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2. APPLICABLE DOCUMENTS

2.1 Government Documents. The following documents of the issue specified contribute to the definition of the interfaces between the GPS Space Segment and the GPS Navigation User Segment, and form a part of this ICD to the extent specified herein.

Specifications

Federal

None

Military

None

Other Government Activity

None

Standards

Federal

None

Military

None

Other Publications

(section removed)

2.2 Non-Government Documents. The following documents of the issue specified contribute to the definition of the interfaces between the GPS Space Segment and the GPS Navigation User Segment and form a part of this ICD to the extent specified herein.

Specifications

None

Other Publications

None

3. REQUIREMENTS

3.1 Interface Definition. As shown in Figure 3-1, the interface between the GPS Space Segment (SS) and the GPS navigation User Segment (US) consists of two radio frequency (RF) links: L1 and L2. Utilizing these links, the space vehicles (SVs) of the SS shall provide continuous earth coverage for signals which provide to the US the ranging codes and system data needed to accomplish the GPS navigation (NAV) mission. These signals shall be available to a suitably equipped user with RF visibility to an SV.

3.2 Interface Identification. The carriers of the L-band links are modulated by up to two bit trains, each of which normally is a composite generated by the Modulo-2 addition of a pseudo-random noise (PRN) ranging code and the downlink system data (referred to as NAV data).

3.2.1 Ranging Codes. Three PRN ranging codes are transmitted: the precision (P) code which is the principal NAV ranging code; the Y-code, used in place of the P-code whenever the anti-spoofing (A-S) mode of operation is activated; and the coarse/acquisition (C/A) code which is used primarily for acquisition of the P (or Y) code (denoted as P(Y)). Appropriate code-division-multiplexing techniques allow differentiating between the SVs even though they all transmit at the same L-band frequencies. The SVs will transmit intentionally "incorrect" versions of the C/A and the P(Y) codes where needed to protect the users from receiving and utilizing anomalous NAV signals as a result of a malfunction in the SV's reference frequency generation system. These two "incorrect" codes are termed non-standard C/A (NSC) and non-standard Y (NSY) codes. However, the requirements regarding Y-code and non-standard codes do not apply to Block I SVs.

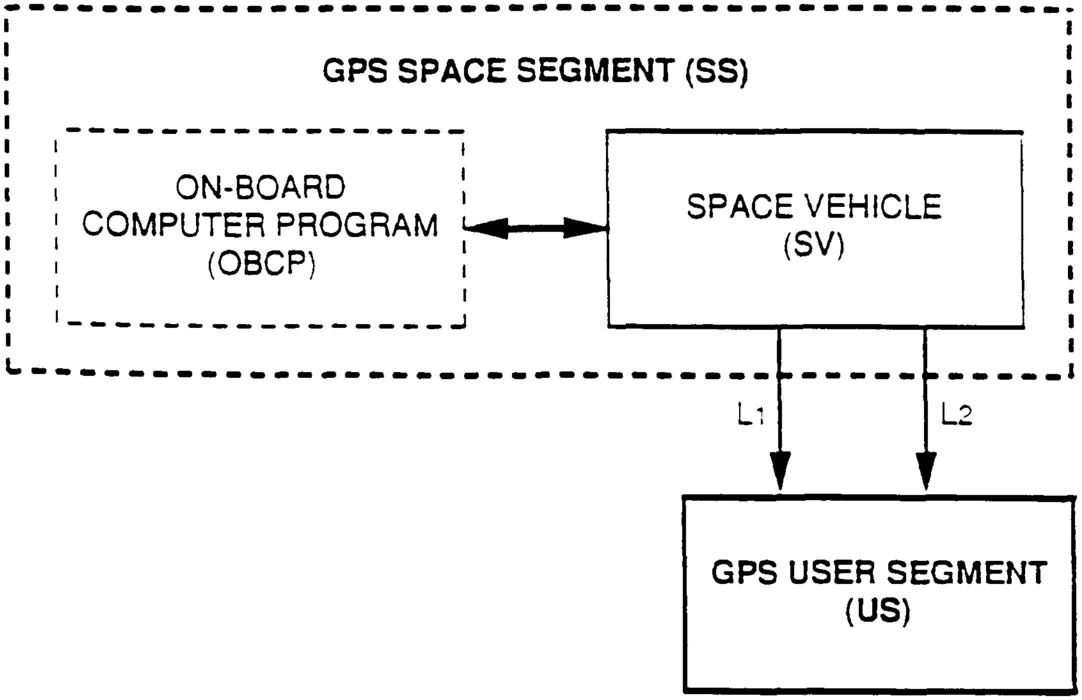


Figure 3-1. Space Vehicle/NAV User Interfaces

3.2.1.1 P-Code. The PRN P-code for SV ID number i is a ranging code, $P_i(t)$, of 7 days in length at a chipping rate of 10.23 MBps. The 7 day sequence is the Modulo-2 sum of two subsequences referred to as X1 and $X2_i$; their lengths are 15,345,000 chips and 15,345,037 chips, respectively. The $X2_i$ sequence is an X2 sequence selectively delayed by 1 to 37 chips thereby allowing the basic code generation technique to produce a set of 37 mutually exclusive P-code sequences of 7 days in length. Of these, 32 are designated for use by SVs, while the remaining 5 are reserved for other purposes (e.g. ground transmitters, etc). Assignment of these code phase segments by SV-ID number (or other use) is given in Table 3-I.

3.2.1.2 Y-Code. The PRN Y-code, used in place of the P-code when the A-S mode of operation is activated, is defined elsewhere and is not available to the general public. The requirements regarding PRN Y-code do not apply to Block I SVs.

3.2.1.3 C/A-Code. The PRN C/A-code for SV ID number i is a Gold code, $G_i(t)$, of 1 millisecond in length at a chipping rate of 1023 Kbps. The $G_i(t)$ sequence is a linear pattern generated by the Modulo-2 addition of two subsequences, G1 and $G2_i$, each of which is a 1023 chip long linear pattern. The epochs of the gold code are synchronized with the X1 epochs of the P-code. As shown in Table 3-I, the $G2_i$ sequence is a G2 sequence selectively delayed by from 5 to 950 chips, thereby generating a set of 36 mutually exclusive C/A-codes. Assignment of these by SV-ID (or other use) is also given in Table 3-I.

3.2.1.4 Non-standard Codes. The NSC and the NSY codes, used to protect the user from a malfunction in the SV's reference frequency system (reference paragraph 3.2.1), are not for utilization by the user and, therefore, are not defined in this document. However, the requirements regarding Y-code and Non-standard codes do not apply to Block I SV's.

Table 3-I. Code Phase Assignments

SV ID No.	GPS PRN Signal No.	Code Phase Selection C/A (G2ᵢ)	Code Phase Selection (X2ᵢ)	Code Delay Chips C/A	Code Delay Chips P	First 10 Chips Octal* C/A	First 12 Chips Octal P
1	1	2 ⊕ 6	1	5	1	1440	4444
2	2	3 ⊕ 7	2	6	2	1620	4000
3	3	4 ⊕ 8	3	7	3	1710	4222
4	4	5 ⊕ 9	4	8	4	1744	4333
5	5	1 ⊕ 9	5	17	5	1133	4377
6	6	2 ⊕ 10	6	18	6	1455	4355
7	7	1 ⊕ 8	7	139	7	1131	4344
8	8	2 ⊕ 9	8	140	8	1454	4340
9	9	3 ⊕ 10	9	141	9	1626	4342
10	10	2 ⊕ 3	10	251	10	1504	4343
11	11	3 ⊕ 4	11	252	11	1642	
12	12	5 ⊕ 6	12	254	12	1750	
13	13	6 ⊕ 7	13	255	13	1764	
14	14	7 ⊕ 8	14	256	14	1772	
15	15	8 ⊕ 9	15	257	15	1775	
16	16	9 ⊕ 10	16	258	16	1776	
17	17	1 ⊕ 4	17	469	17	1156	
18	18	2 ⊕ 5	18	470	18	1467	
19	19	3 ⊕ 6	19	471	19	1633	
20	20	4 ⊕ 7	20	472	20	1715	
21	21	5 ⊕ 8	21	473	21	1746	
22	22	6 ⊕ 9	22	474	22	1763	
23	23	1 ⊕ 3	23	509	23	1063	
24	24	4 ⊕ 6	24	512	24	1706	
25	25	5 ⊕ 7	25	513	25	1743	
26	26	6 ⊕ 8	26	514	26	1761	
27	27	7 ⊕ 9	27	515	27	1770	
28	28	8 ⊕ 10	28	516	28	1774	
29	29	1 ⊕ 6	29	859	29	1127	
30	30	2 ⊕ 7	30	860	30	1453	
31	31	3 ⊕ 8	31	861	31	1625	
32	32	4 ⊕ 9	32	862	32	1712	
***	33	5 ⊕ 10	33	863	33	1745	
***	34 **	4 ⊕ 10	34	950	34	1713	
***	35	1 ⊕ 7	35	947	35	1134	
***	36	2 ⊕ 8	35	948	36	1456	
***	37 **	4 ⊕ 10	37	950	37	1713	4343

* In the octal notation for the first 10 chips of the C/A code as shown in this column, the first digit (1) represents a "1" for the first chip and the last three digits are the conventional octal representation of the remaining 9 chips. (For example, the first 10 chips of the C/A code for PRN Signal Assembly No. 1 are: 1100100000).

** C/A codes 34 and 37 are common.

*** PRN sequences 33 through 37 are reserved for other uses (e.g. ground transmitters).

⊕ = "exclusive or"

NOTE: The code phase assignments constitute inseparable pairs, each consisting of a specific C/A and a specific P code phase, as shown above.

3.2.2 NAV Data. The system data, D(t), includes SV ephemerides, system time, SV clock behavior data, status messages and C/A to P (or Y) code handover information, etc. The 50 bps data is Modulo-2 added to the P(Y) and C/A codes; the resultant bit-trains are used to modulate the L1 and L2 carriers. For a given SV, the data train D(t), if present, is common to the P(Y) and C/A codes on both the L1 and L2 channels. The content and characteristics of data ID number 2 are given in Appendix II of this document. Data ID number 1 is no longer in use.

3.2.3 L-Band Signal Structure. The L1 link consists of two carrier components which are in phase quadrature with each other. Each carrier component is bi-phase shift key (BPSK) modulated by a separate bit train. One bit train is the Modulo-2 sum of the P(Y)-code and NAV data, while the other is the Modulo-2 sum of the C/A-code and the NAV data. The L2 link is BPSK modulated by only one of those two bit trains; the bit train to be used for L2 modulation is selected by ground command. A third modulation mode is also selectable on the L2 channel by ground command: it utilizes the P(Y)-code without the NAV data as the modulating signal. For a particular SV, all transmitted signal elements (carriers, codes and data) are coherently derived from the same on-board frequency source.

3.3 Interface Criteria. The criteria specified in the following define the requisite characteristics of the SS/US interface.

3.3.1 Composite Signal. The following criteria define the characteristics of the composite L-band signals.

3.3.1.1 Frequency Plan. The L-band signals shall be contained within two 20.46-MHz bands centered about L1 and L2. The carrier frequencies for the L1 and L2 signals shall be coherently derived from a common frequency source within the SV. The nominal frequency of this source -- as it appears to an observer on the ground -- is 10.23 MHz. To compensate for relativistic effects, the output frequency of the SV's frequency standard -- as it would appear to an observer located in the SV -- is 10.23 MHz offset by a $\Delta f/f = -4.46 \times 10^{-10}$ or a $\Delta f = -4.57 \times 10^{-3}$ Hz. This is equal to 10.22999999543 MHz. The nominal carrier frequencies (f_o) shall be 1575.42 MHz, and 1227.6 MHz for L1 and L2, respectively.

3.3.1.2 Correlation Loss Correlation loss is defined as the difference between the SV power received in a 20.46 MHz bandwidth and the signal power recovered in an ideal correlation receiver of the same bandwidth. On the L1 and L2 channels, the worst case correlation loss occurs when the carrier is modulated by the sum of the P(Y) code and the NAV data stream. For this case, the correlation loss apportionment shall be as follows:

1. SV modulation imperfections 0.6 dB.
2. Ideal UE receiver waveform distortion 0.4 dB (due to 20.46 MHz filter).

3.3.1.3 Carrier Phase Noise. The phase noise spectral density of the unmodulated carrier shall be such that a phase locked loop of 10 Hz one-sided noise bandwidth shall be able to track the carrier to an accuracy of 0.1 radians rms.

3.3.1.4 Spurious Transmissions. In-band spurious transmissions shall be at least 40 dB below the unmodulated L1 and L2 carriers over the allocated 20.46 MHz channel bandwidth.

3.3.1.5 Phase Quadrature. The two L1 carrier components modulated by the two separate bit trains (C/A-code plus data and P(Y)-code plus data) shall be in phase quadrature (within ±100 milliradians) with the C/A signal carrier lagging the P signal carrier by 90 degrees. Referring to the phase of the P Carrier when $P_i(t)$ equals zero as the "zero phase angle", the P(Y) and C/A code generator output shall control the respective signal phases in the following manner: when $P_i(t)$ equals one, a 180-degree phase reversal of the P carrier occurs; when $G_i(t)$ equals one, the C/A carrier advances 90 degrees; when $G_i(t)$ equals zero, the C/A carrier shall be retarded 90 degrees (such that when $G_i(t)$ changes state, a 180-degree phase reversal of the C/A carrier occurs). The resultant nominal composite transmitted signal phases as a function of the binary state of the modulating signals are as shown in Table 3-II.

3.3.1.6 User-Received Signal Levels. The SV shall provide L1 and L2 navigation signals in accordance with the minimum levels specified in Table 3-III into a 3 dB_i linearly polarized user receiving antenna (located near ground) at worst normal orientation, when the SV is above a 5-degree elevation angle. Additional related data is provided as supporting material in paragraph 6.3.1.

3.3.1.7 Equipment Group Delay. Equipment group delay is defined as the delay between the L-band radiated output of a specific SV (measured at the antenna phase center) and the output of the SV's on-board frequency source; the delay consists of a bias term and an uncertainty. The bias term is of no concern to the US since it is included in clock correction parameters relayed in the NAV data, and is therefore accounted for by the user computations of system time (reference paragraph 20.3.3.3.3.1). The uncertainty (variation) of the delay as well as the difference between the L1 versus the L2 delays are defined in the following.

3.3.1.7.1 Group Delay Uncertainty. The effective uncertainty of the group delay shall not exceed 3.0 nanoseconds (two sigma).

Table 3-II. Composite L1 Transmitted Signal Phase

Nominal Composite L1 Signal Phase*	Code State	
	P	C/A
0°	0	0
-70.5°	1	0
+109.5°	0	1
180°	1	1

*Relative to 0, 0 code state with positive angles leading and negative angles lagging.

Table 3-III. Received Minimum RF Signal Strength

Channel	Signal		
	P (Y)		C/A
L1	−163.0 dBW		−160.0 dBW
L2	−166.0 dBW	or	−166.0 dBW

3.3.1.7.2 Group Delay Differential. The group delay differential between the radiated L1 and L2 P(Y) signals is specified as consisting of random plus bias components. The mean differential is defined as the bias component and will be either positive or negative. For a given navigation payload redundancy configuration, the absolute value of the mean differential delay shall not exceed 15.0 nanoseconds. The random variations about the mean shall not exceed 3.0 nanoseconds (two sigma).

3.3.1.8 Signal Coherence. All transmitted signals for a particular SV shall be coherently derived from the same on-board frequency standard; all digital signals shall be clocked in coincidence with the PRN transitions for the P-signal and occur at the P-signal transition speed. On the L1 channel the data transitions of the two modulating signals (i.e. that containing the P(Y)-code and that containing the C/A-code) shall be such that the average time difference between the transitions does not exceed 10 nanoseconds (two sigma).

3.3.1.9 Signal Polarization. The transmitted signal shall be right-hand circularly polarized. The ellipticity for L1 shall be no worse than 1.2 dB for the angular range of $\pm$ 14.3 degrees from boresight; for L2, it shall be no worse than 3.2 dB for the angular range of $\pm$ 14.3 degrees from boresight.

3.3.2 PRN Code Characteristics. The characteristics of the P and the C/A codes are defined below in terms of their structure and the basic method used for generating them. The characteristics of the Y-code are defined elsewhere. Figure 3-2 depicts a simplified block diagram of the scheme for generating the 10.23 Mbps $P_i(t)$ and the 1.023 Mbps $G_i(t)$ patterns (referred to as P and C/A codes respectively), and for Modulo-2 summing these patterns with the NAV data bit train, D(t), which is clocked at 50 bps. The resultant composite bit trains are then used to modulate the L-band carriers.

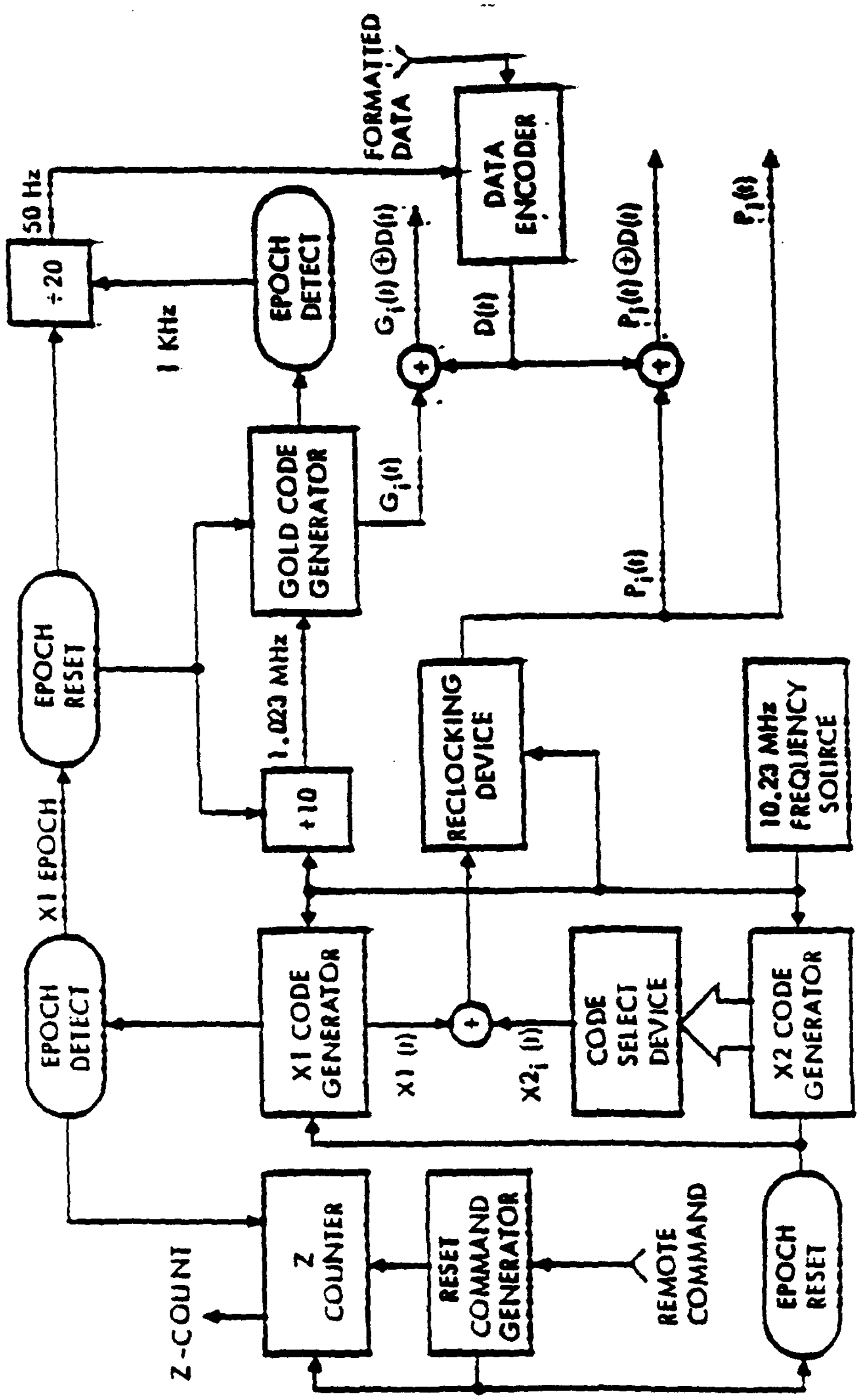


Figure 3-2. Generation of Codes and Modulating Signals

3.3.2.1 Code Structure. The $P_i(t)$ pattern (P-code) is generated by the Modulo-2 summation of two PRN codes, X1(t) and X2(t - iT), where T is the period of one P-code chip and equals $(1.023 \times 10^7)^{-1}$ seconds, while i is an integer of 1 through 37. This allows the generation of 37 unique P(t) code phases (identified in Table 3-I) using the same basic code generator.

The linear $G_i(t)$ pattern (C/A-code) is the Modulo-2 sum of two 1023-bit linear patterns, G1 and $G2_i$. The latter sequence is selectively delayed by an integer number of chips to produce 36 unique G(t) patterns (defined in Table 3-I).

3.3.2.2 P-Code Generation. Each $P_i(t)$ pattern is the Modulo-2 sum of two extended patterns clocked at 10.23 Mbps (X1 and $X2_i$). X1 itself is generated by the Modulo-2 sum of the output of two 12-stage registers (X1A and X1B) short cycled to 4092 and 4093 chips respectively. When the X1A short cycles are counted to 3750, the X1 epoch is generated. The X1 epoch occurs each 1.5 seconds, after 15,345,000 chips of the X1 pattern have been generated. The polynomials for X1A and X1B, as referenced to the shift register input, are:

X1A: $1 + X^6 + X^8 + X^{11} + X^{12}$, and
X1B: $1 + X^1 + X^2 + X^5 + X^8 + X^9 + X^{10} + X^{11} + X^{12}$

Samples of the relationship between shift register taps and the exponents of the corresponding polynomial, referenced to the shift register input, are shown in Figures 3-3, 3-4, 3-5, and 3-6.

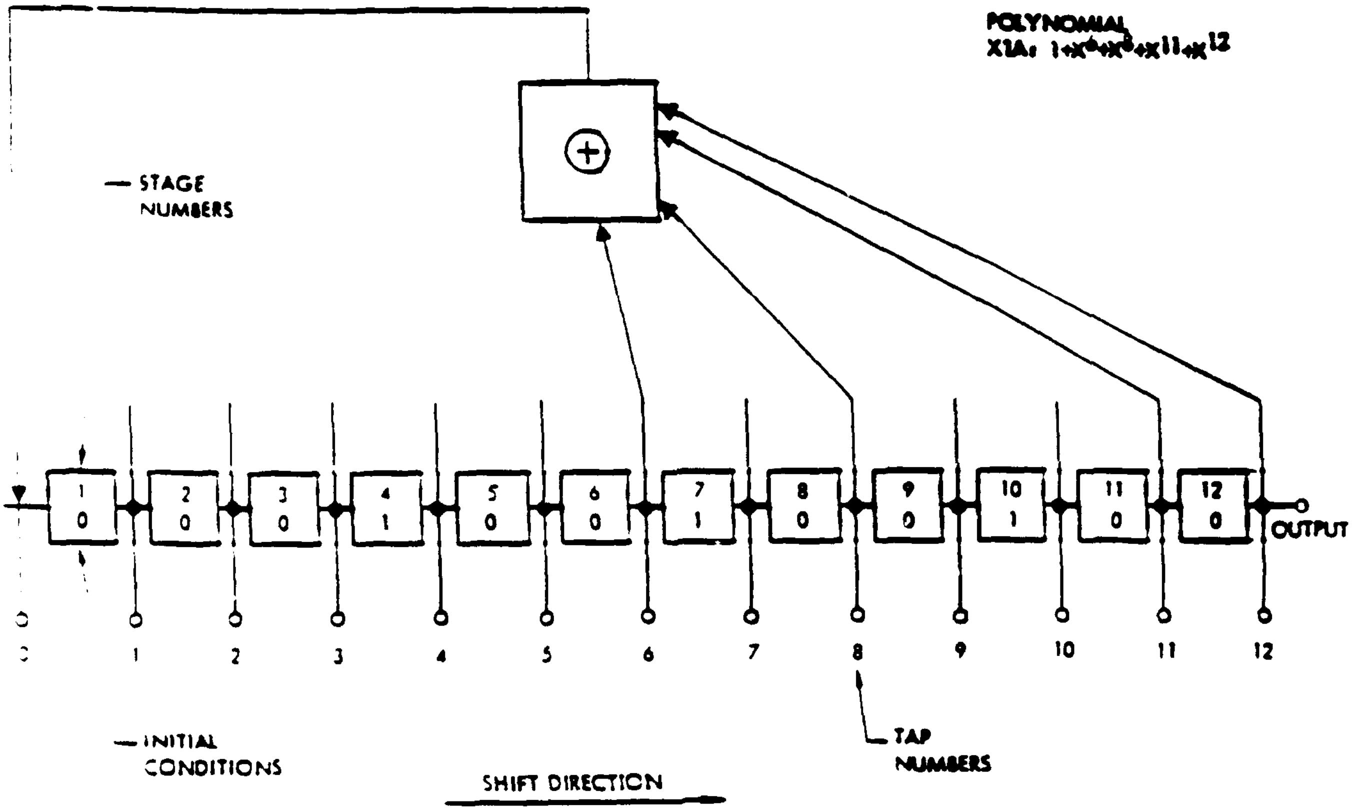


Figure 3-3. X1A Shift Register Generator Configuration

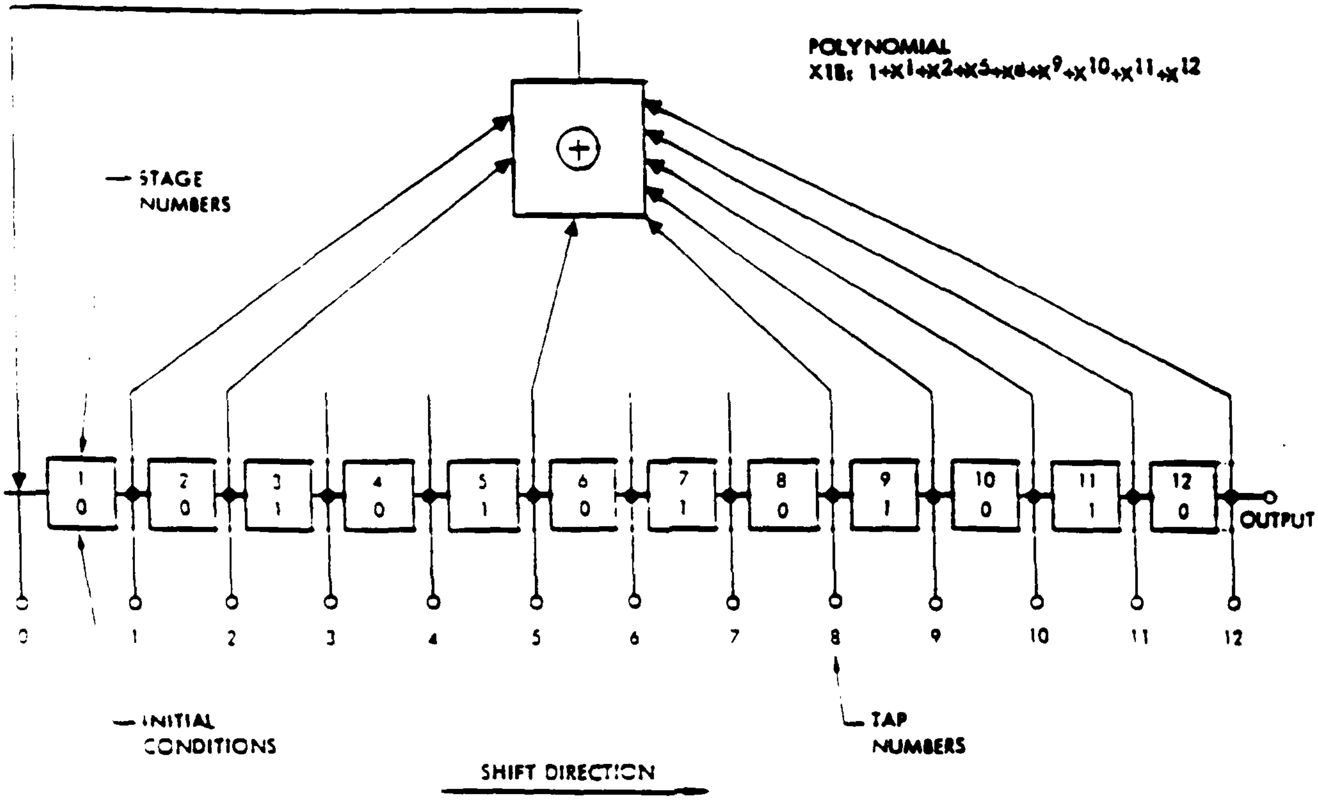


Figure 3-4. X1B Shift Register Generator Configuration

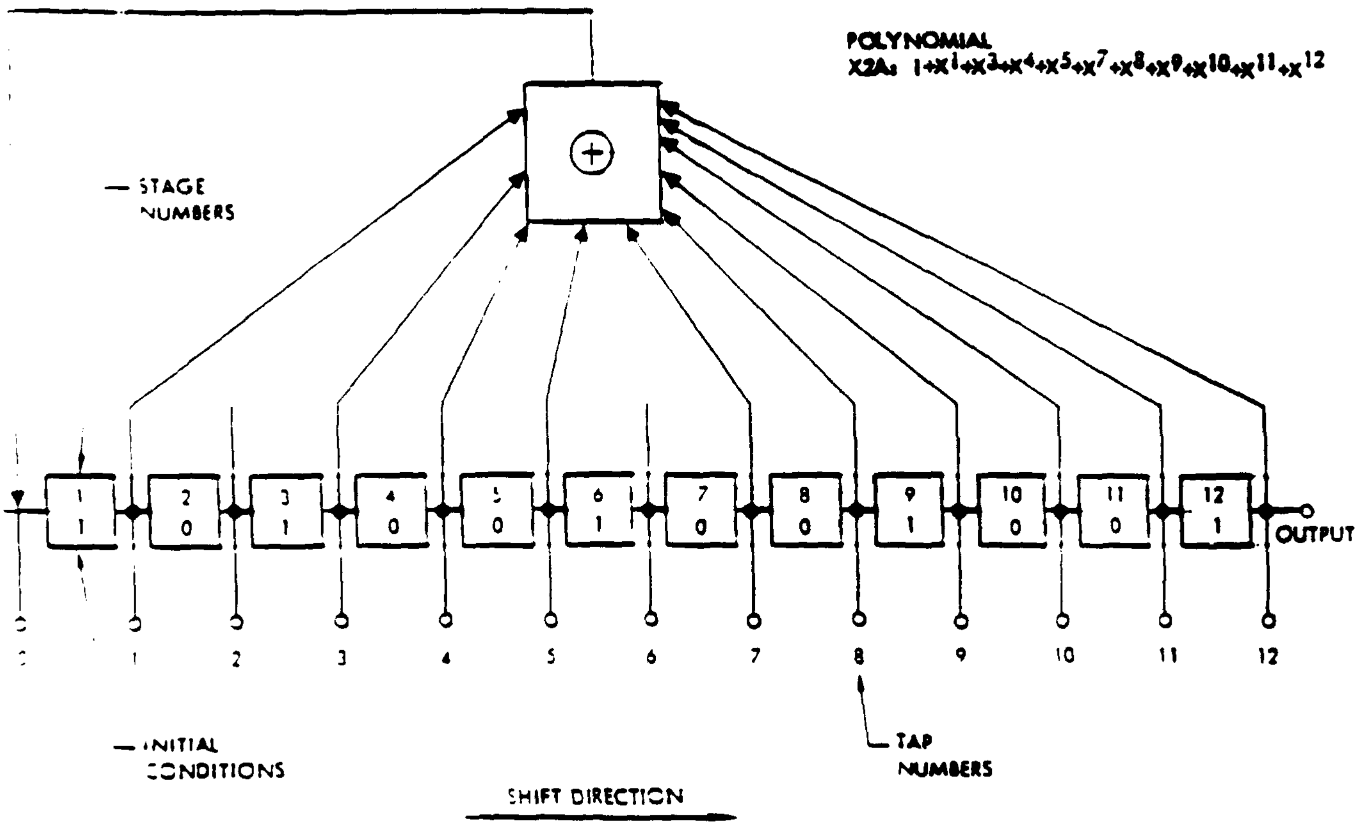


Figure 3-5. X2A Shift Register Generator Configuration

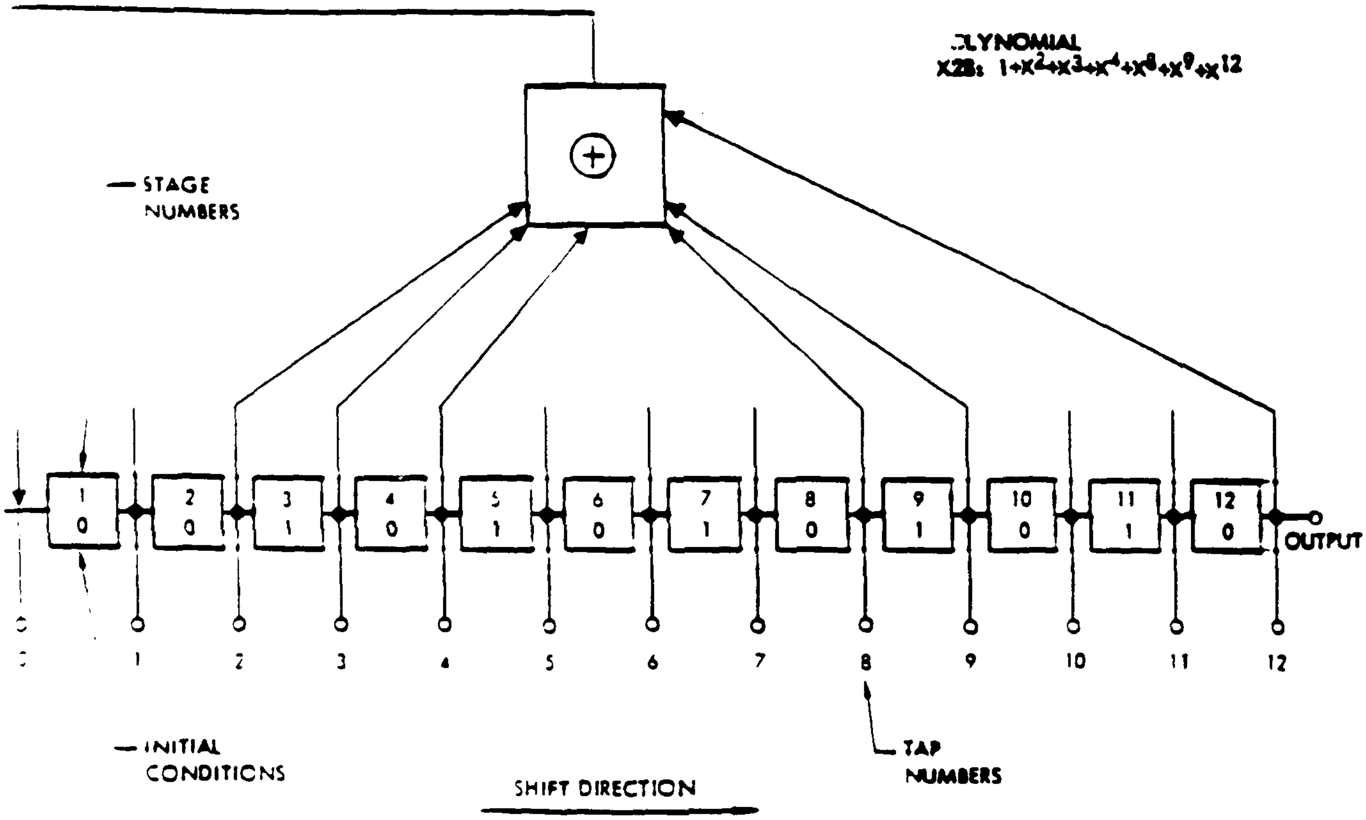


Figure 3-6. X2B Shift Register Generator Configuration

The state of each generator can be expressed as a code vector word which specifies the binary sequence constant of each register as follows: (a) the vector consists of the binary state of each stage of the register, (b) the stage 12 value appears at the left followed by the v lues of the remaining states in order of descending stage numbers, and (c) the shift direction is from lower to higher stage number with stage 12 providing the current output. This code vector convention represents the present output and 11 future outputs in sequence. Using this convention, at each X1 epoch, the X1A shift register is initialized to code vector 001001001000 and the X1B shift register is initialized to code vector 010101010100. The first chip of the X1A sequence and the first chip of an X1B sequence occur simultaneously in the first chip interval of any X1 period.

The natural 4095 chip cycles of these generating sequences are shortened to cause precession of the X1B sequence with respect to the X1A sequence during subsequent cycles of the X1A sequence in the X1 period. Reintialization of the X1A shift register produces a 4092 chip sequence by omitting the last 3 chips (001) of the natural 4095 chip X1A sequence. Reintialization of the X1B shift register produces a 4093 chip sequence by omitting the last 2 chips (01) of the natural 4095 chip X1B sequence. This results in the phase of the X1B sequence lagging by one chip for each X1A cycle in the X1 period.

The X1 period is defined as 3750 X1A cycles (15,345,000 chips) which is not an integer number of X1B cycles. To accommodate this situation, the X1B shift register is held in the final state (chip 4093) of its 3749th cycle. It remains in this state until the X1A shift register completes its 3750th cycle (343 additional chips). The completion of the 3750th X1A cycle establishes the next X1 epoch which reinitializes both the X1A and X1B shift registers starting a new X1 cycle.

The $X2_i$ sequences are generated by first producing an X2 sequence and then delaying it by a selected integer number of chips, i, ranging from 1 to 37. Each of the $X2_i$ sequences is then Modulo-2 added to the X1 sequence thereby producing up to 37 unique P(t) sequences.

The X2A and X2B shift registers, used to generate X2, operate in a similar manner to the X1A and X1B shift registers. They are short-cycled, X2A to 4092 and X2B to 4093, so that they have the same relative precession rate as the X1 shift registers. X2A epochs are counted to include 3750 cycles and X2B is held in the last state at 3749 cycle until X2A completes its 3750th cycle. The polynomials for X2A and X2B, as referenced to the shift register input, are:

X2A: $1 + X^1 + X^3 + X^4 + X^5 + X^7 + X^8 + X^9 + X^{10} + X^{11} + X^{12}$, and

X2B: $1 + X^2 + X^3 + X^4 + X^8 + X^9 + X^{12}$

(The initialization vector for X2A is 100100100101 and for X2B is 010101010100).

The X2A and X2B epochs are made to precess with respect to the X1A and X1B epochs by causing the X2 period to be 37 chips longer than the X1 period. When X2A is in the last state of its 3750th cycle and X2B is in the last state of its 3749th cycle, their transitions to their respective initial states are delayed by 37 chip time durations.

At the beginning of the GPS week, X1A, X1B, X2A, and X2B shift registers are initialized to produce the first chip of the week. The precession of the shift registers with respect to X1A continues until the last X1A period of the GPS week interval. During this particular X1A period, X1B, X2A, and X2B are held when reaching the last state of their respective cycles until that X1A cycle completes (see Table 3-IV). At this point, all four shift registers are initialized and provide the first chip of the new week.

Figure 3-7 shows a functional P-code mechanization. Signal component timing is shown in Figure 3-8, while the end-of-week reset timing and the final code vector states are given in Tables 3-IV and 3-V, respectively.

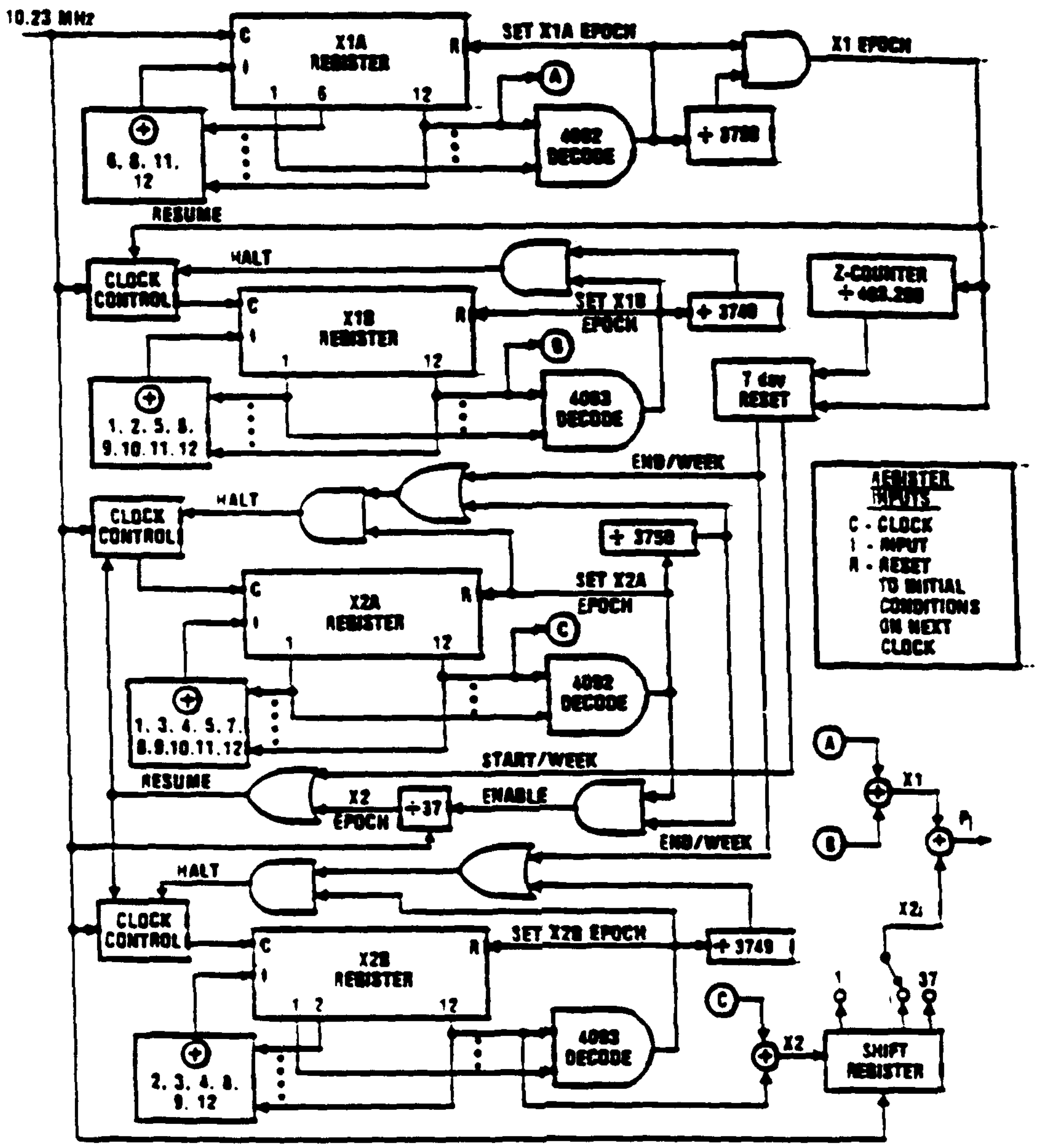


Figure 3-7. P-Code Generation

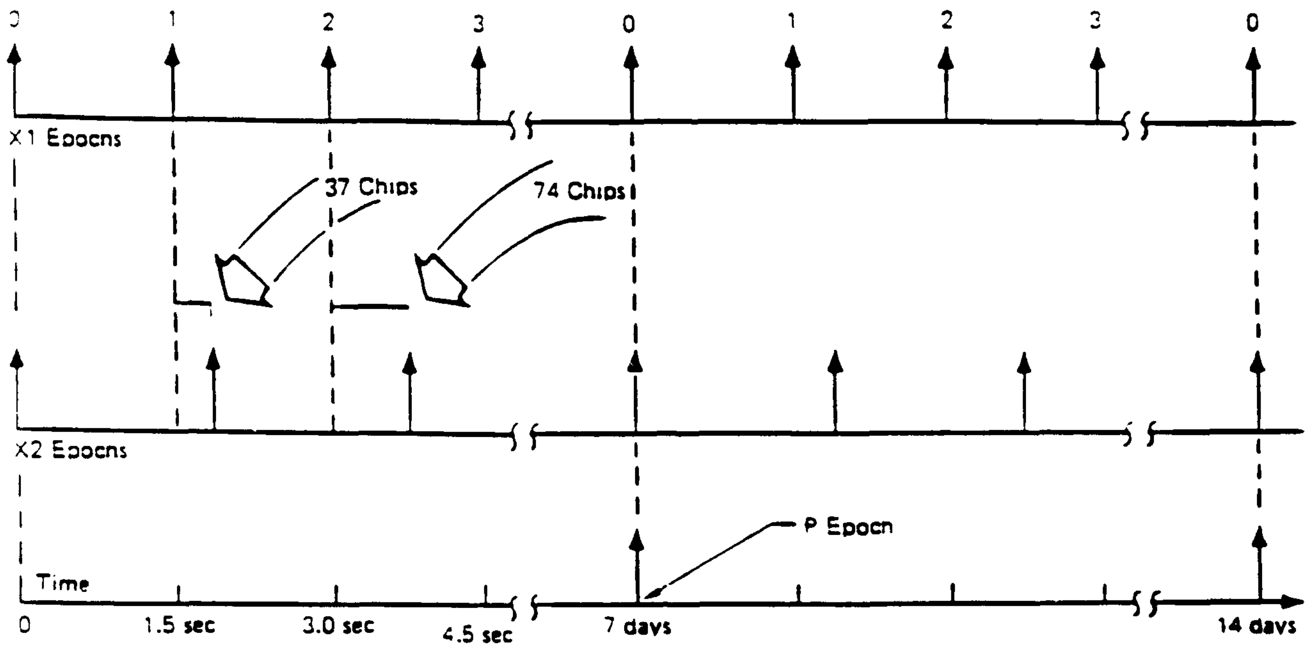


Figure 3-6. P-Code Signal Component Timing

Table 3-IV. P-Code Reset Timing
(Last 400 μsec of 7 Day Period)

Code Chip			
X1A-Code	X1B-Code	X2A-Code	X2B-Code
1	345	1070	967
. . .	. . .	. . .	. . .
3023	3367	$\boxed{4092}$	3989
. . .	. . .	. . .	. . .
3127	3471	4092	$\boxed{4093}$
. . .	. . .	. . .	. . .
3749	$\boxed{4093}$	4092	4093
. . .	. . .	. . .	. . .
$\boxed{4092*}$	4093	4092	4093

*Last Chip of week

Time ↓

Table 3-V. Final Code Vector States

	X1A-Code	X1B-Code	X2A-Code	X2B-Code
Chip No. Vector State	4091 100010010010	4092 100101010101	4091 111001001001	4092 000101010101
Chip No. Vector State	4092 000100100100	4093 001010101010	4092 110010010010	4093 001010101010
Vector State for 1st Chip following Epoch	001001001000	010101010100	100100100101	010101010100

Note: First Chip in each sequence is output bit whose leading edge occurs simultaneously with the epoch.

3.3.2.3 C/A-Code Generation. Each $G_i(t)$ sequence is a 1023-bit Gold-code which is itself the Modulo-2 sum of two 1023-bit linear patterns, G1 and $G2_i$. The $G2_i$ sequence is formed by effectively delaying the G2 sequence by an integer number of chips ranging from 5 to 950. The G1 and G2 sequences are generated by 10-stage shift registers having the following polynomials as referred to in the shift register input (see Figure 3-9 and 3-10).

$$G1 = X^{10} + X^3 + 1, \text{ and}$$
$$G2 = X^{10} + X^9 + X^8 + X^6 + X^3 + X^2 + 1.$$

The initialization vector for the G1 and G2 sequences is (1111111111). The G1 and G2 shift registers are initialized at the P-coder X1 epoch. The G1 and G2 registers are clocked at 1.023 MHz derived from the 10.23 MHz P-coder clock. The initialization by the X1 epoch phases the 1.023 MHz clock to insure that the first chip of the C/A code begins at the same time as the first chip of the P-code.

The effective delay of the G2 sequence to form the $G2_i$ sequence is accomplished by combining the output of two stages of the G2 shift register by Modulo-2 addition (see Figure 3-11). Thirty-six of the possible combinations are selected, one to correspond to each of 36 different P-codes. Table 3-1 contains a tabulation of the G2 shift register taps selected and their corresponding P-code $X2_i$ and PRN signal numbers together with the first several chips of each resultant PRN code. Timing relationships related to the C/A code are shown in Figure 3-12.

POLYNOMIAL G1: $1 + X^3 + X^{10}$:

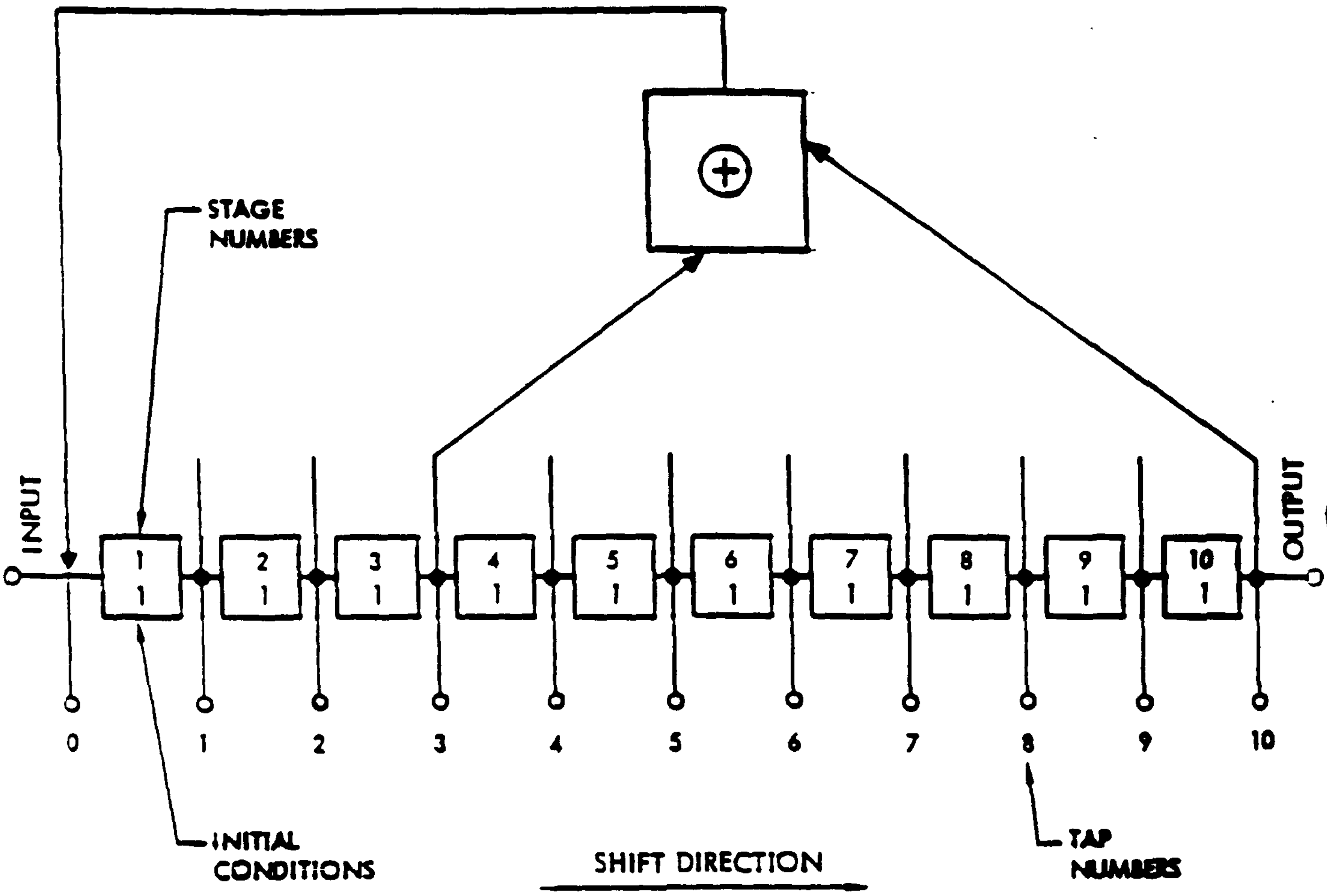


Figure 3-9. G1 Shift Register Generator Configuration

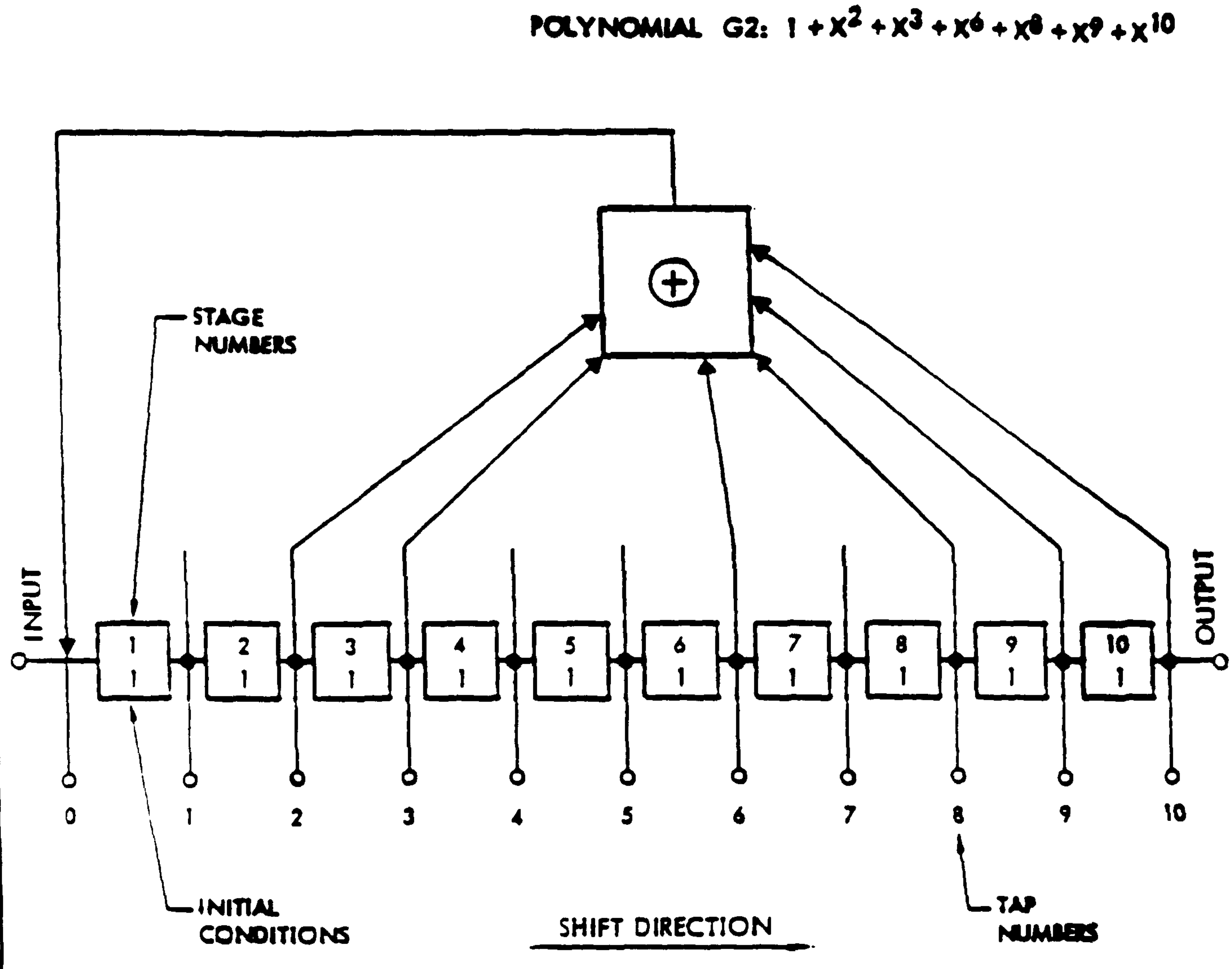


Figure 3-10. G2 Shift Register Generator Configuration

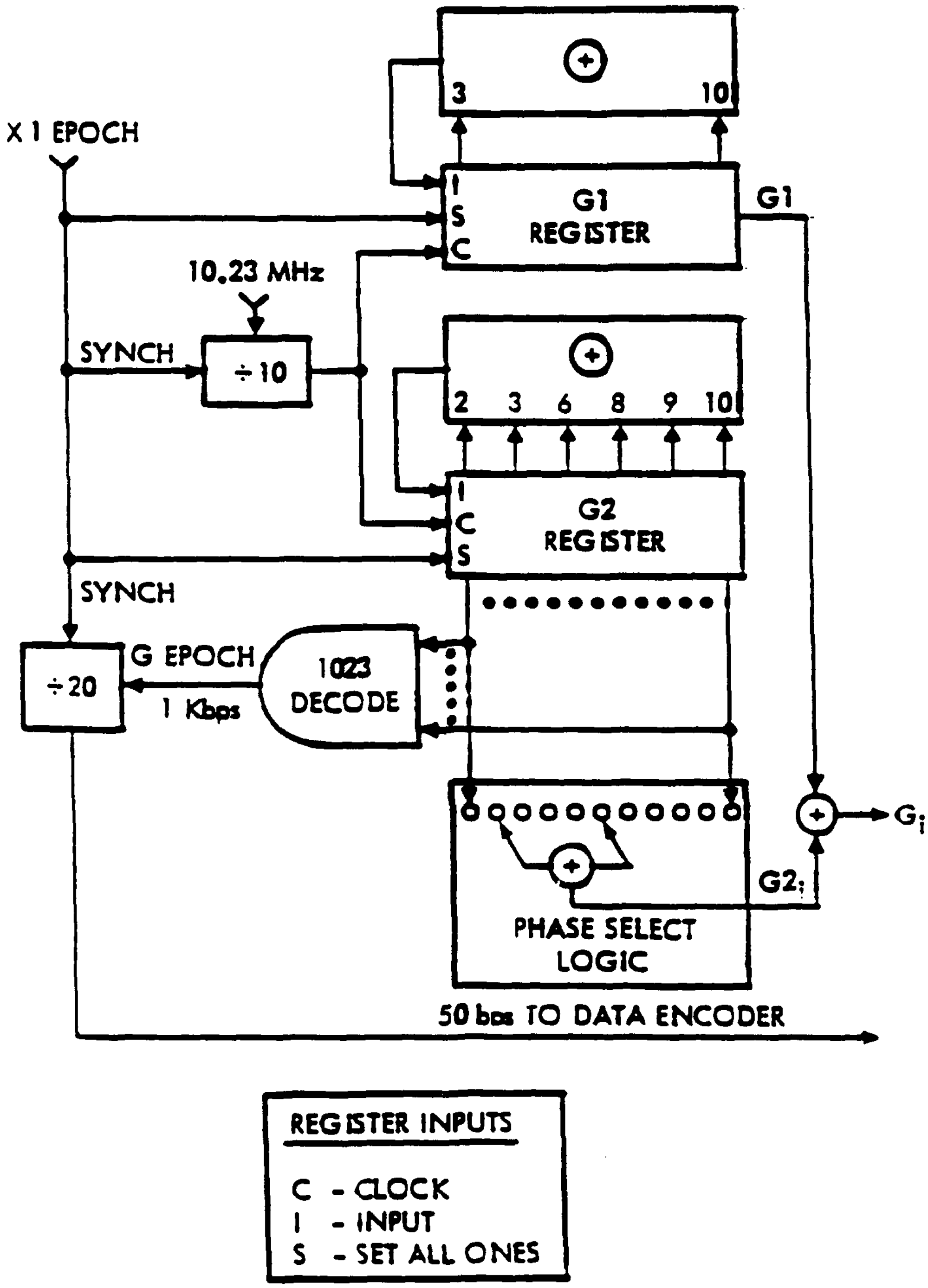


Figure 3-11. C/A-Code Generation

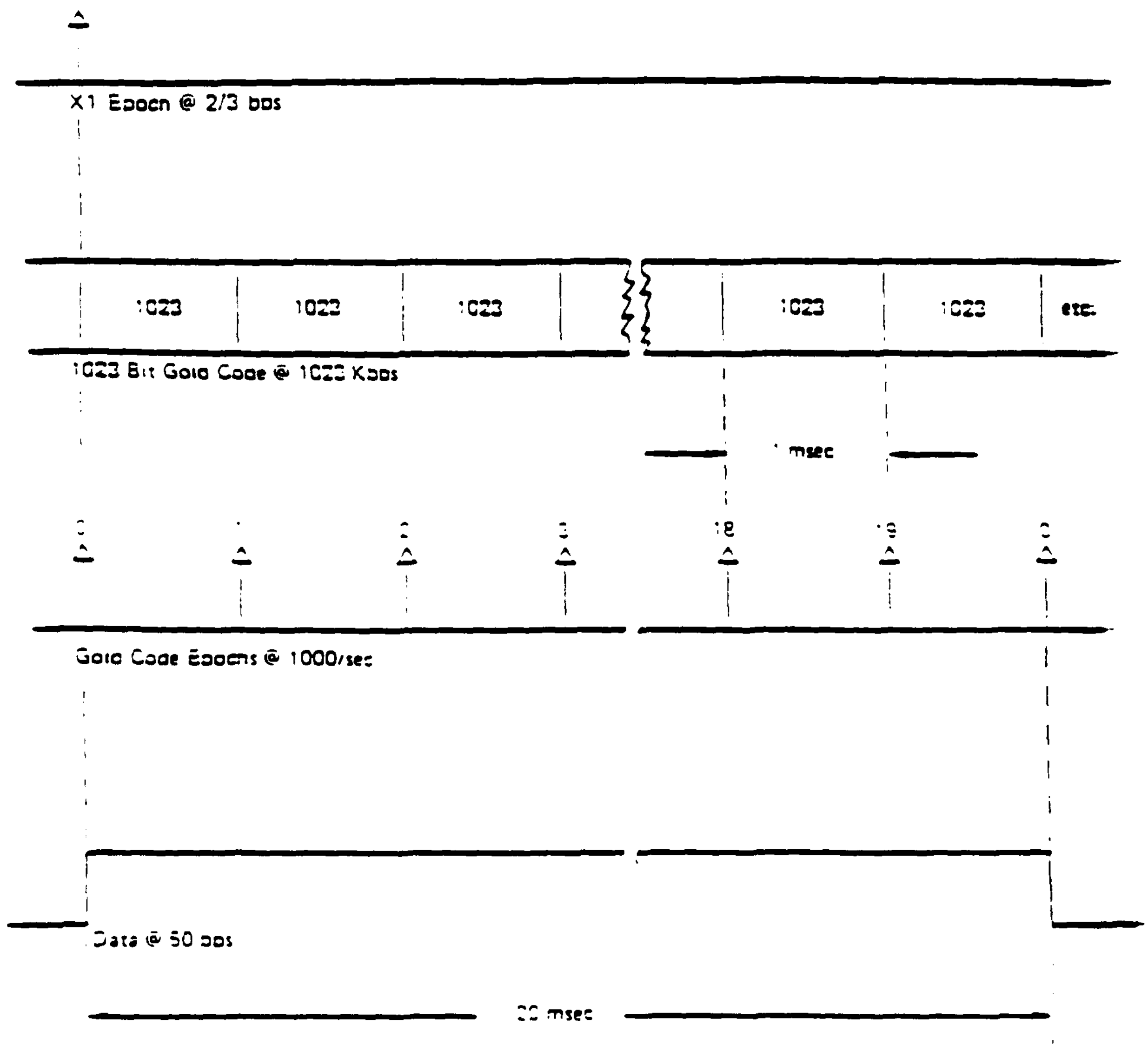


Figure 3-12. C/A Code Timing Relationships

3.3.3 Navigation Data. The content and format of the NAV data for data ID number 2 is given in Appendix II of this document (reference paragraph 20.3.3.5.1.1). Data ID number 1 is no longer in use.

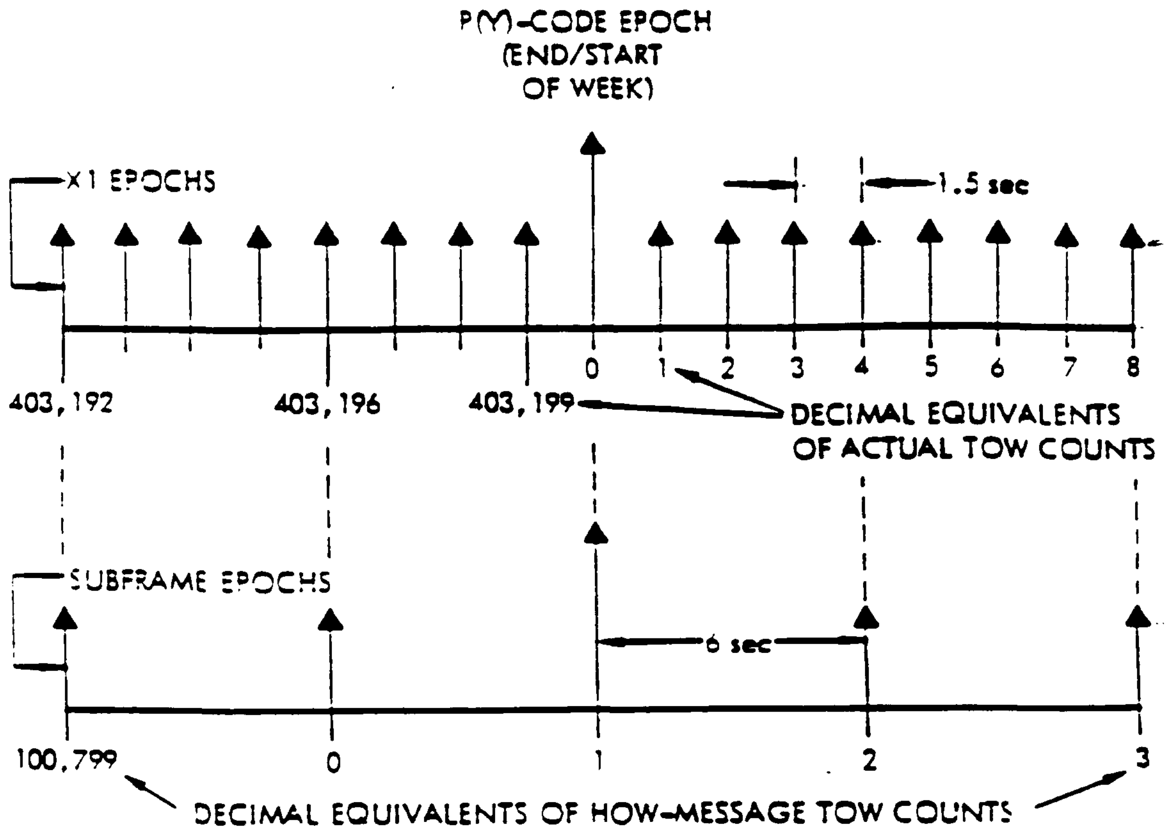
3.3.4 GPS Time and SV Z-Count. GPS time is established by the Control Segment and is referenced to a UTC (as maintained by the U.S. Naval Observatory) zero time-point defined as midnight on the night of January 5, 1980/morning of January 6, 1980. The largest unit used in stating GPS time is one week defined as 604,800 seconds. GPS time may differ from UTC because GPS time shall be a continuous time scale, while UTC is corrected periodically with an integer number of leap seconds. There also is an inherent but bounded drift rate between the UTC and GPS time scales. The OCS shall control the GPS time scale to be within one microsecond of UTC (Modulo one second).

The NAV data contains the requisite data for relating GPS time to UTC. The accuracy of this data during the transmission interval shall be such that it shall relate GPS time (maintained by the MCS of the CS) to UTC (USNO) within 90 nanoseconds (one sigma). Range error components (e.g. SV clock and position) contribute to the GPS time transfer error, and under normal operating circumstances (two frequency time transfers from SV(s) whose navigation message indicates a URA of eight meters or less), this corresponds to a 97 nanosecond (one sigma) apparent uncertainty at the SV. Propagation delay errors and receiver equipment biases unique to the user add to this time transfer uncertainty.

In each SV the X1 epochs of the P-code offer a convenient unit for precisely counting and communicating time. Time stated in this manner is referred to as Z-count, which is given as a 29-bit binary number consisting of two parts as follows:

a. The binary number represented by the 19 least significant bits of the Z-count is referred to as the time of week (TOW) count and is defined as being equal to the number of X1 epochs that have occurred since the transition from the previous week. The count is short-cycled such that the range of the TOW-count is from 0 to 403,199 X1 epochs (equaling one week) and is reset to zero at the end of each week. The TOW-count's zero state is defined as that X1 epoch which is coincident with the start of the present week. This epoch occurs at (approximately) midnight Saturday night-Sunday morning, where midnight is defined as 0000 hours on the Universal Coordinated Time (UTC) scale which is nominally referenced to the Greenwich Meridian. Over the years the occurrence of the "zero state epoch" may differ by a few seconds from 0000 hours on the UTC scale since UTC is periodically corrected with leap seconds while the TOW-count is continuous without such correction. To aid rapid ground lock-on to the P-code signal, a truncated version of the TOW-count, consisting of its 17 most significant bits, is contained in the handover word (HOW) of the L-Band downlink data stream; the relationship between the actual TOW-count and its truncated HOW version is illustrated by Figure 3-13.

b. The ten most significant bits of the Z-count are a binary representation of the sequential number assigned to the present GPS week (Modulo 1024). The range of this count is from 0 to 1023 with its zero state being defined as the week which starts with the X1 epoch occurring at (approximately) midnight on the night of January 5, 1980/morning of January 6, 1980.



NOTES:

1. TO AID IN RAPID GROUND LOCK-ON THE HAND-OVER WORD (HOW) OF EACH SUBFRAME CONTAINS A TRUNCATED TIME-OF-WEEK (TOW) COUNT.
2. THE HOW IS THE SECOND WORD IN EACH SUBFRAME (REFERENCE PARAGRAPH 20.3.3.2).
3. THE HOW-MESSAGE TOW COUNT CONSISTS OF THE 17 MSB's OF THE ACTUAL TOW COUNT AT THE START OF THE NEXT SUBFRAME.
4. TO CONVERT FROM THE HOW-MESSAGE TOW COUNT TO THE ACTUAL TOW COUNT AT THE START OF THE NEXT SUBFRAME, MULTIPLY BY FOUR.
5. THE FIRST SUBFRAME STARTS SYNCHRONOUSLY WITH THE END/START OF WEEK EPOCH.

Figure 3-13. Time Line Relationship of HOW Message

4. NOT APPLICABLE

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5. NOT APPLICABLE

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6 NOTES

6.1 Acronyms.

A-S	- Anti-Spoofing
BPSK	- Bi-Phase Shift Key
CS	- Control Segment
DN	- Day Number
EAROM	- Electrically Alterable Read-Only Memory
GPS	- Global Positioning System
HOW	- Handover Word
ICD	- Interface Control Document
ID	- Identification
IODC	- Issue of Data, Clock
IODE	- Issue of Data, Ephemeris
LSB	- Least Significant Bit
LSF	- Leap Seconds Future
MCS	- Master Control Station
MSB	- Most Significant Bit
NAV	- Navigation
NSC	- Non-Standard C/A-Code
NSY	- Non-Standard Y-Code
OBCP	- On-Board Computer Program
OCS	- Operational Control Segment
PRN	- Pseudo Random Noise
RF	- Radio Frequency
RMS	- Root Mean Square
SA	- Selective Availability
SS	- Space Segment
SV	- Space Vehicle
TBD	- To Be Determined
TBS	- To Be Supplied

TLM	- Telemetry
TOW	- Time Of Week
UE	- User Equipment
URA	- User Range Accuracy
URE	- User Range Error
US	- User Segment
USNO	- U.S. Naval Observatory
UTC	- Universal Coordinated Time
WGS 84	- World Geodetic System 1984
WN	- Week Number

6.2 Definitions

6.2.1 User Range Accuracy. User range accuracy (URA) is a statistical indicator of the ranging accuracies obtainable with a specific SV. URA is a one-sigma estimate of the user range errors in the navigation data for the transmitting satellite. It includes all errors for which the Space and Control Segments are responsible. It does not include any errors introduced in the user set or the transmission media. While the URA may vary over a given subframe fit interval, the URA index (N) reported in the NAV message corresponds to the maximum value of URA anticipated over the fit interval.

6.2.2 Operational Interval Definitions. The following three operational intervals have been defined. These labels will be used to refer to differences in the interface definition as time progresses from SV acceptance of the last navigation data upload.

6.2.2.1 Normal Operations. The SV is undergoing normal operations whenever the fit interval flag (reference paragraph 20.3.3.4.3.1) is zero.

6.2.2.2 Short-term Extended Operations. The SV is undergoing short-term extended operations whenever the fit interval flag is one and the IODE (reference paragraph 20.3.4.4) is less than 240.

6.2.2.3 Long-term Extended Operations. The SV is undergoing long-term extended operations whenever the fit interval flag is one and the IODE is in the range 240-255.

Note: the DoD Navigation User Segment and Time Transfer User have no requirement to operate, and may not operate properly, whenever any SV is operating in long-term extended operations.

6.3 Supporting Material

6.3.1 Received Signals. The guaranteed minimum user-received signal levels are defined in paragraph 3.3.1.6. As additional supporting material Figure 6-1 illustrates the minimum power of the near-ground user-received L1 and L2 signals as a function of SV elevation angle using the following assumptions: (a) the signal is measured at the output of a 3 dB_i linearly polarized receiving antenna, (b) the SV is above a 5 degree elevation angle, (c) the received signal levels are observed within the in-band allocation defined in paragraph 3.3.1.1, (d) the atmospheric path loss is 2.0 dB, and (e) the SV attitude error is 0.5 degrees (towards reducing signal level). The actual SV attitude error will not exceed ±0.5 degrees after the SV has stabilized to its final orbital state.

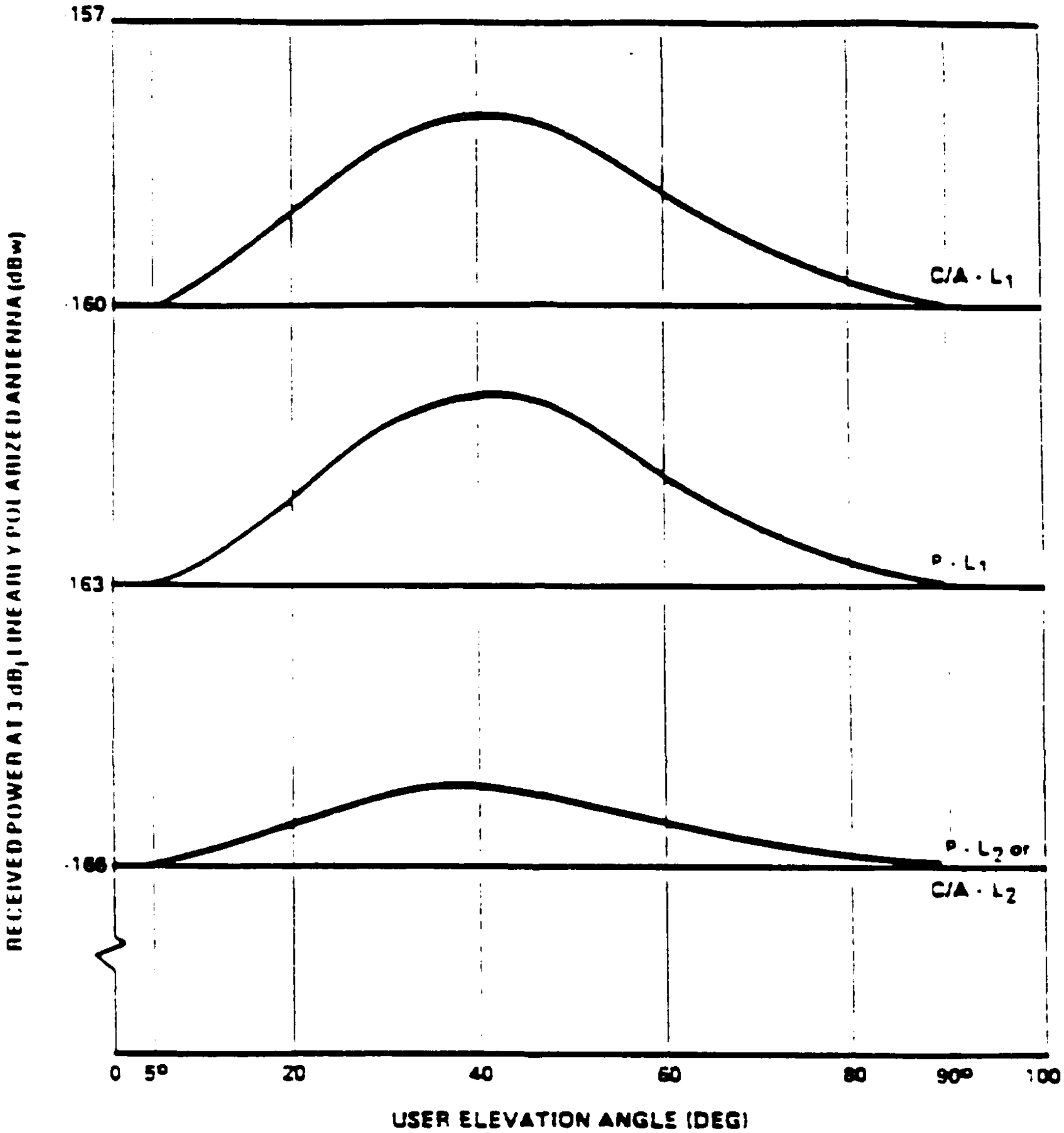

Figure 6-1. User Received Minimum Signal Levels

Higher received signal levels can be caused by such factors as SV attitude errors, mechanical antenna alignment errors, transmitter power output variations due to temperature variations, voltage variations and power amplifier variations, and due to a variability in link atmospheric path loss. The maximum received signal levels as a result of these factors is not expected to exceed -155.5 dBw and -153.0 dBw, respectively, for the P(Y) and C/A components of the L1 channel, nor -158.0 dBw for either signal on the L2 channel. This estimate assumes that the receiving antenna characteristics are as described above, the atmospheric loss is 0.6 dB and the SV attitude error is 0.5 degree (towards increased signal level).

10. APPENDIX I. LETTERS OF EXCEPTION

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20. APPENDIX II. GPS NAVIGATION DATA STRUCTURE FOR DATA ID NO. 2

20.1 Scope. This appendix describes the specific GPS navigation (NAV) data structure denoted by data ID number 2. This data ID number, when transmitted as part of the NAV data, shall be represented by the two-bit binary notation of 01. Data ID number 1 is no longer in use.

20.2 Applicable Documents

20.2.1 Government Documents. In addition to the documents listed in paragraph 2.1, the following documents of the issue specified contribute to the definition of the NAV data related interfaces and form a part of this Appendix to the extent specified herein.

Specifications
None

Standards
None

Other Publications
None

20.2.2 Non-Government Documents. In addition to the documents listed in paragraph 2.2, the following documents of the issue specified contribute to the definition of the NAV data related interfaces and form a part of this Appendix to the extent specified herein.

Specifications
None

Other Publications
None

20.3 Requirements

20.3.1 Data Characteristics. The data stream shall be transmitted by the SV on the L1 and L2 channels at a rate of 50 bps. The data stream, when present, shall be common to both of those L-band frequencies, irrespective of the PRN ranging code(s) used.

20.3.2 Message Structure. As shown in Figure 20-1, the message structure shall utilize a basic format of a 1500 bit long frame made up of five subframes, each subframe being 300 bits long. Subframes 4 and 5 shall be subcommutated 25 times each, so that a complete data message shall require the transmission of 25 full frames. The 25 versions of subframes 4 and 5 shall be referred to herein as pages 1 through 25 of each subframe. Each subframe shall consist of ten words, each 30 bits long; the MSB of all words shall be transmitted first.

Each subframe and/or page of a subframe shall contain a telemetry (TLM) word and a handover word (HOW), both generated by the SV, and shall start with the TLM/HOW pair. The TLM word shall be transmitted first, immediately followed by the HOW. The latter shall be followed by eight data words, each of which shall be generated by the CS. Each word in each frame shall contain parity (reference Section 20.3.5). The SV generates (calculates) parity for the TLM and HOW words only; the CS generates parity for all other words of each frame.

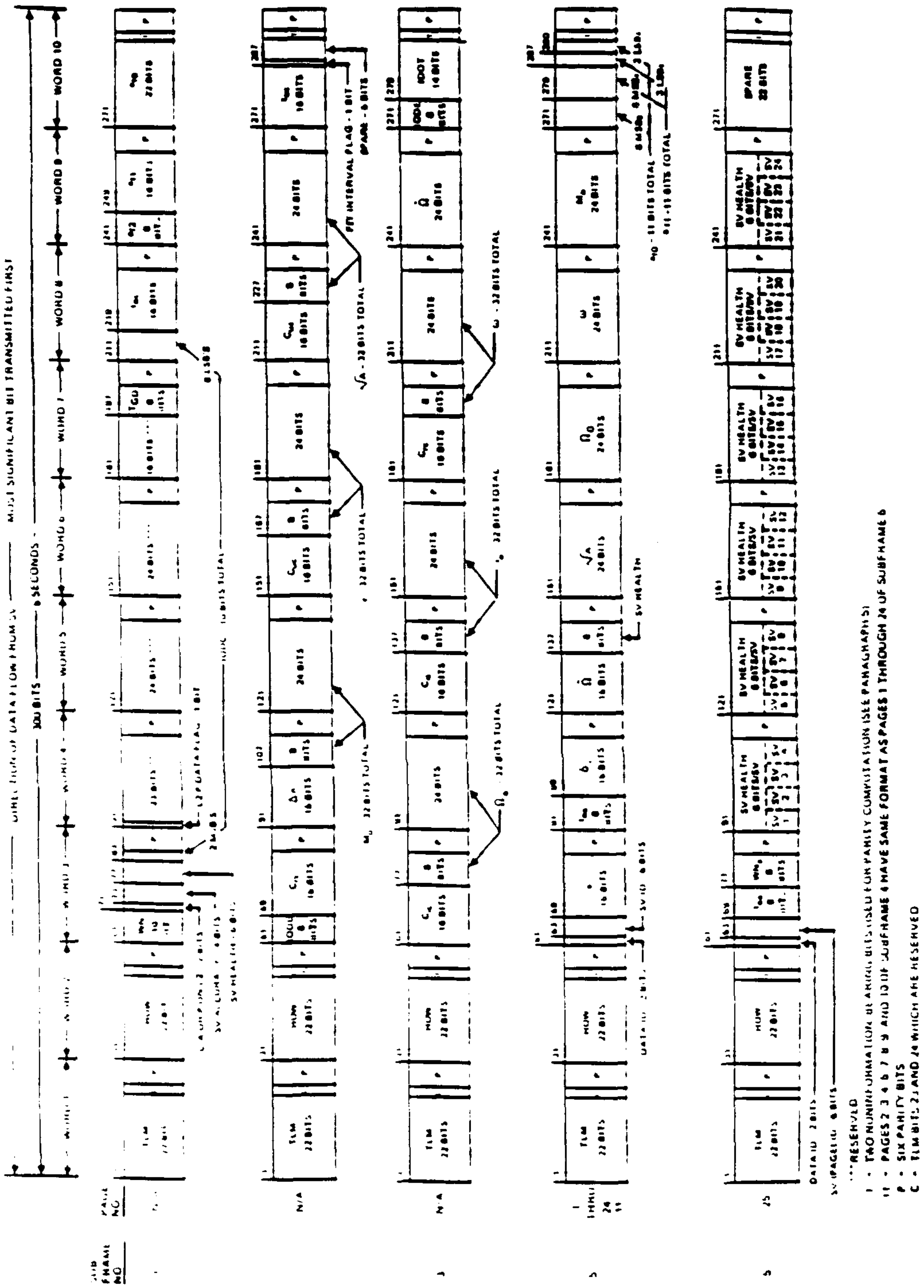
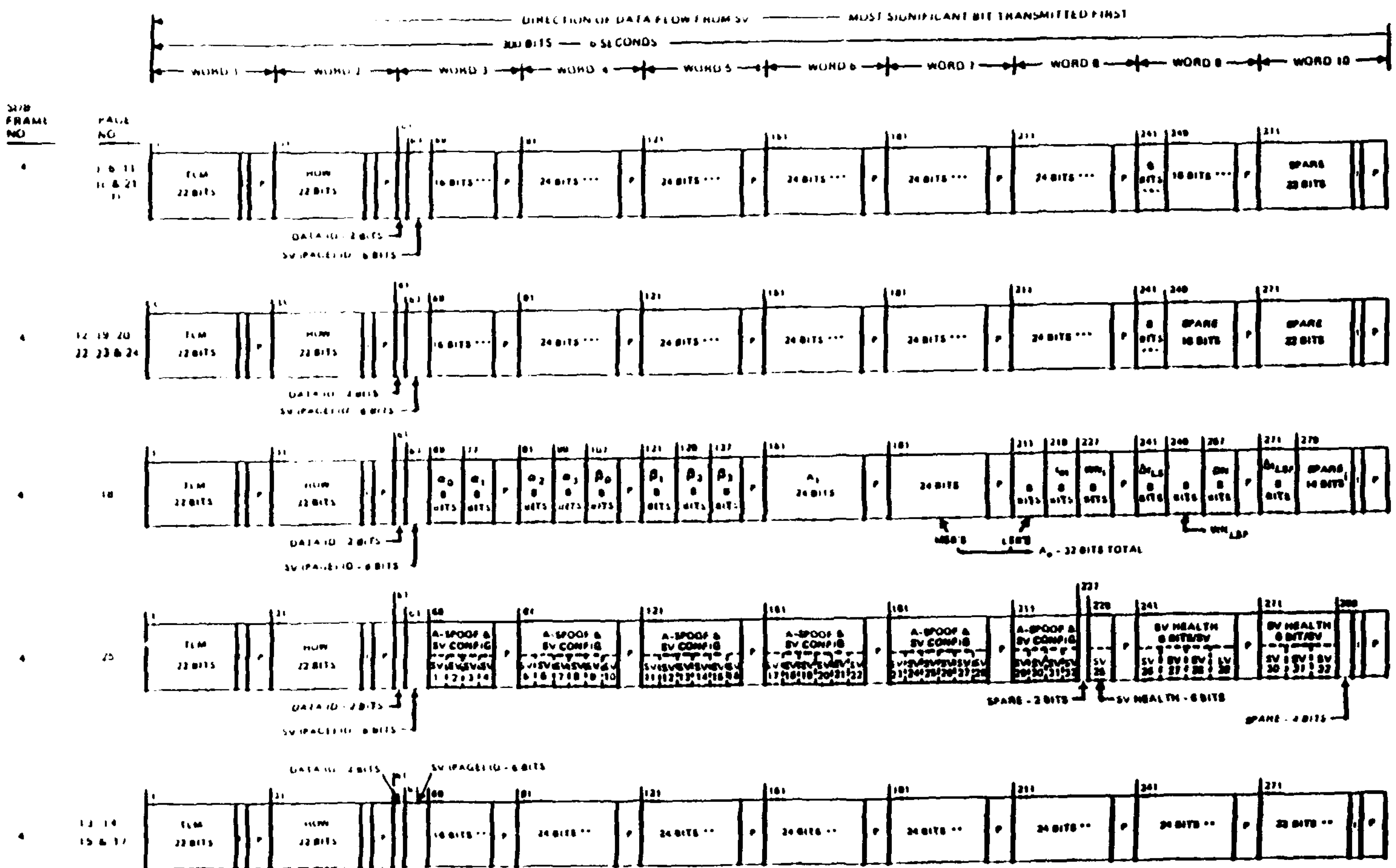


Figure 20-1. Data Format (Sheet 1 of 2)



**THE INDICATED PORTIONS OF WORDS 3 THROUGH 10 OF PAGES 13, 14, AND 15 ARE SPARES WHILE THOSE OF PAGE 17 ARE RESERVED FOR SPECIAL MESSAGES (PLUS SPARES) PER PARAGRAPH 20.3.3.5.1.8

***RESERVED

t - TWO NONINFORMATION BEARING BITS USED FOR PARITY COMPUTATION (SEE PARAGRAPH 5)

tt - PAGES 2, 3, 4, 5, 7, 8, 9 AND 10 OF SUBFRAME 4 HAVE SAME FORMAT AS PAGES 1 THROUGH 24 OF SUBFRAME 5

P - SIX PARITY BITS

C - TLM BITS 23 AND 24 WHICH ARE RESERVED

Figure 20-1. Data Format (Sheet 2 of 2)

The memory retention of Block II SVs (SV configuration 001 -- reference paragraph 20.3.3.5.1.6) will determine the duration of data transmission. Alternating ones and zeros will be transmitted in words 3 through 10 in place of the normal NAV data whenever the SV cannot locate the requisite valid control or data element in its on-board computer memory. The following specifics apply to this default action: (a) the parity of the affected words will be invalid, (b) the two trailing bits of word 10 will be zeros (to allow the parity of subsequent subframes to be valid -- reference paragraph 20.3.5), (c) if the problem is the lack of a data element, only the directly related subframe(s) will be treated in this manner, (d) if a control element cannot be located, this default action will be applied to all subframes and all subframes will indicate ID = 1 (i.e., an ID-code of 001) in the HOW (reference paragraph 20.3.3.2) and (e) certain failures of data which may occur in the SV memory or during an upload will cause the SV to transmit in Non-standard codes (NSC and NSY) which would preclude normal use by the US. Normal NAV data transmission will be resumed by the SV whenever a valid set of elements becomes available.

Whenever Block I SVs (SV configuration 000 -- reference paragraph 20.3.3.5.1.6) reach the end of the uploaded data, they will transmit a pattern of ones and zeros in words 3 through 10 of each subframe with two trailing zeros in word 10. Further, the Block I SVs do not have the capability of transmitting alternating ones and zeros in words 3 through 10 in place of the normal NAV data in default cases specified in the preceding paragraph.

20.3.3 Message Content. The format and contents of the TLM word and the HOW, as well as those of words three through ten of each subframe/page, are described in the following subparagraphs. The timing of the subframes and pages is covered in Section 20.3.4.

20.3.3.1 Telemetry Word. Each TLM word is 30 bits long, occurs every six seconds in the data frame, and is the first word in each subframe/page. The format shall be as shown in Figure 20-2. Bit 1 is transmitted first. Each TLM word shall begin with a preamble, followed by the TLM message, two reserved bits, and six parity bits. The TLM message contains information needed by the authorized user.

20.3.3.2 Handover Word (HOW). The HOW shall be 30 bits long and shall be the second word in each subframe/page, immediately following the TLM word. A HOW occurs every 6 seconds in the data frame. The format and content of the HOW shall be as shown in Figure 20-2. The MSB is transmitted first. The HOW begins with the 17 MSBs of the time-of-week (TOW) count. (The full TOW count consists of the 19 LSBs of the 29-bit Z-count). These 17 bits correspond to the TOW-count at the X1 epoch which occurs at the start (leading edge) of the next following subframe (reference paragraph 3.3.4).

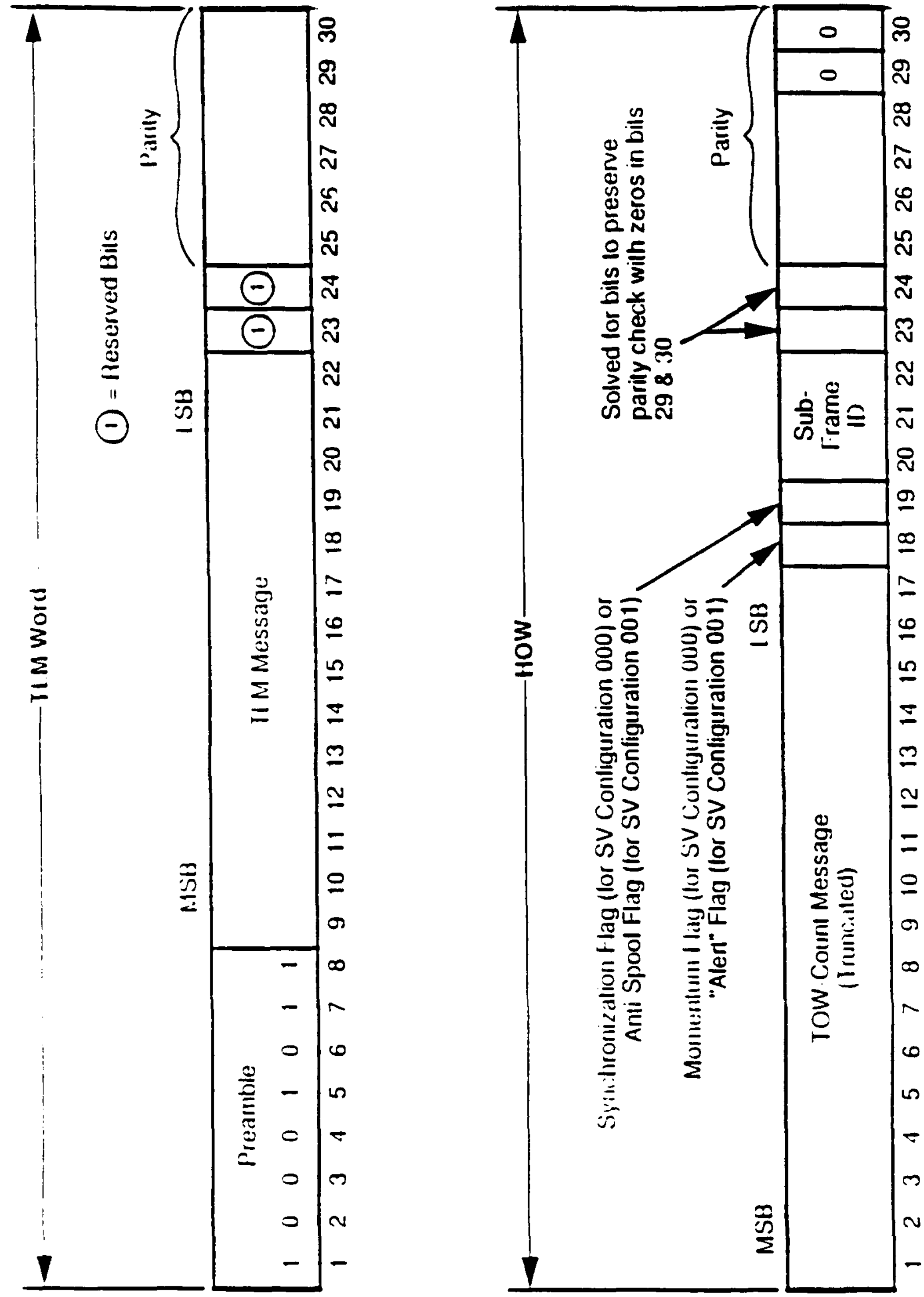


Figure 20-2. TLM and HOW Formats

Bit 18 is used in two ways: (a) on SVs that are designated by configuration code 000, bit 18 is the roll momentum dump flag with a "1" in this bit-position indicating that a non-conservative (thruster type) momentum dump has occurred since the last upload (this flag is reset at a new end-of message transmission at the conclusion of the next upload); and (b) on SVs designated by configuration code 001, bit 18 is an "alert" flag. When this flag is raised (bit 18 = "1"), it shall indicate to the unauthorized user that the SV URA may be worse than indicated in subframe 1 and that he shall use that SV at his own risk. The authorized user shall refer to ICD-GPS-203 and/or ICD-GPS-207 (see note in paragraph 2.1).

Bit 19 also has a dual role: (a) on SVs that are designated by configuration code 000 in page 25 of subframe 4, bit 19 is used as a synchronization flag; and (b) on SVs designated by configuration code 001, bit 19 is an anti-spoof (A-S) flag.

When used as a synchronization flag, a "0" in bit position 19 indicates that the SV is in synchronism, which is defined as the condition in which the leading edge of the TLM word is coincident with the X1 epoch. If bit 19 is a "1", this condition may not exist; i.e., the SV is not in synchronism, and further data from this SV should not be used since it may be erroneous. When used as an A-S flag, a "1" in bit-position 19 indicates that the A-S mode is ON in that SV.

Bits 20, 21, and 22 of the HOW provide the ID of the subframe in which that particular HOW is the second word; the ID code shall be as follows:

Subframe	ID Code
1	001
2	010
3	011

Subframe	ID Code
4	100
5	101

20.3.3.3 Subframe 1. The content of words three through ten of subframe 1 are defined below, followed by related algorithms and material pertinent to use of the data.

20.3.3.3.1 Subframe 1 Content. The third through tenth words of subframe 1 shall each contain six parity bits as their LSBs; in addition, two non-information bearing bits shall be provided as bits 23 and 24 of word ten for parity computation purposes. The remaining 190 bits of words three through ten shall contain the clock parameters and other data described in the following.

The clock parameters describe the SV time scale during the period of validity. The parameters in a data set shall be valid during the interval of time in which they are transmitted and shall remain valid for an additional period of time after transmission of the next data set has started. The timing information for subframes, pages, and data sets is covered in Section 20.3.4.

20.3.3.3.1.1 Week Number. The ten MSBs of word three shall contain the ten MSBs of the 29-bit Z-count as qualified herein. These ten bits shall represent the number of the current GPS week at the start of the data set transmission interval with "all zeros" indicating week "0". The GPS week number increments at each end/start of week epoch. For Block II SVs in long-term extended operations, beginning approximately 28 days after upload, the transmission week number may not correspond to the actual GPS week number due to curve fit intervals that cross week boundaries.

20.3.3.3.1.2 Code(s) on L2 Channel. Bits 11 and 12 of word three shall indicate which codes(s) is (are) commanded ON for the L2 channel, as follows:

00 = Reserved,

01 = P code ON,

10 = C/A code ON.

20.3.3.3.1.3 SV Accuracy. Bits 13 through 16 of word three shall give the URA index of the SV (reference paragraph 6.2.1) for the unauthorized user. The URA index (N) is an integer in the range of 0 through 15 and has the following relationship to the URA of the SV:

URA INDEX	URA (meters)
0	0.0 < URA ≤ 2.4
1	2.4 < URA ≤ 3.4
2	3.4 < URA ≤ 4.85
3	4.85 < URA ≤ 6.85
4	6.85 < URA ≤ 9.65
5	9.65 < URA ≤ 13.65
6	13.65 < URA ≤ 24.0
7	24.0 < URA ≤ 48.0
8	48.0 < URA ≤ 96.0
9	96.0 < URA ≤ 192.0
10	192.0 < URA ≤ 384.0
11	384.0 < URA ≤ 768.0
12	768.0 < URA ≤ 1536.0
13	1536.0 < URA ≤ 3072.0
14	3072.0 < URA ≤ 6144.0
15	6144.0 < URA (or no accuracy prediction is available - unauthorized users are advised to use the SV at their own risk.)

For each URA index (N), users may compute a nominal URA value (X) as given by:

- If the value of N is 6 or less, $X = 2^{(1 + N/2)}$,
- If the value of N is 6 or more, but less than 15, $X = 2^{(N - 2)}$,
- N = 15 shall indicate the absence of an accuracy prediction and shall advise the unauthorized user to use that SV at his own risk.

For N = 1, 3, and 5, X should be rounded to 2.8, 5.7, and 11.3 meters, respectively.

20.3.3.3.1.4 SV Health. The six-bit health indication given by bits 17 through 22 of word three refers to the transmitting SV. The MSB shall indicate a summary of the health of the NAV data, where

0 = all NAV data are OK
1 = some or all NAV data are bad.

The five LSBs shall indicate the health of the signal components in accordance with the codes given in paragraph 20.3.3.5.1.3. The health indication shall be given relative to the "as designed" capabilities of each SV (as designated by the configuration code - see paragraph 20.3.3.5.1.6). Accordingly, any SV which does not have a certain capability will be indicated as "healthy" if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from a user standpoint and does not require that capability.

Additional SV health data are given in subframes 4 and 5. The data given in subframe 1 may differ from that shown in subframes 4 and/or 5 of other SV's since the latter may be updated at a different time.

20.3.3.3.1.5 <u>Issue of Data, Clock (IODC)</u>. Bits 23 and 24 of word three in subframe 1 shall be the two MSBs of the ten-bit IODC term; bits one through eight of word eight in subframe 1 shall contain the eight LSBs of the IODC. The IODC indicates the issue number of the data set and thereby provides the user with a convenient means of detecting any change in the correction parameters. Constraints on the IODC as well as the relationship between the IODC and the IODE (issue of data, ephemeris) terms are defined in paragraph 20.3.4.4.

<u>Long-term Extended Operations</u>. For Block II SVs, whenever the fit interval flag indicates a fit interval greater than 4 hours, the IODC can be used to determine the actual fit interval of the data set (reference section 20.3.4.4).

20.3.3.3.1.6 <u>Data Flag for L2 P-Code</u>. When bit 1 of word four is a "1", it shall indicate that the NAV data stream was commanded OFF on the P-code of the L2 channel.

20.3.3.1.7 (Reserved)

20.3.3.3.1.8 <u>Estimated Group Delay Differential</u>. Bits 17 through 24 of word seven contain the L1–L2 correction term, T_{GD}, for the benefit of "L1 only" or "L2 only" users; the related user algorithm is given in paragraph 20.3.3.3.3.

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Figure 20-3. (Reserved)

Figure 20-4. (Reserved)

20.3.3.3.1.9 SV Clock Correction. Bits 9 through 24 of word eight, bits 1 through 24 of word nine, and bits 1 through 22 of word ten contain the parameters needed by the users for apparent SV clock correction (t_{oc}, a_{f2}, a_{f1}, a_{f0}). The related algorithm is given in paragraph 20.3.3.3.3.

20.3.3.3.2 Subframe 1 Parameter Characteristics. For those parameters whose characteristics are not fully defined in Section 20.3.3.3.1, the number of bits, the scale factor of the LSB (which shall be the last bit received), the range, and the units shall be as specified in Table 20-I.

20.3.3.3.3 User Algorithms for Subframe 1 Data. The algorithms defined below (a) allow all users to correct the code phase time received from the SV with respect to both SV code phase offset and relativistic effects, (b) permit the "single frequency" (L1 or L2) user to compensate for the effects of SV group delay differential (the user who utilizes both frequencies does not require this correction, since the clock parameters account for the induced effects), and (c) allow the "two frequency" (L1 or L2) user to correct for the group propagation delay due to ionospheric effects (the single frequency user may correct for ionospheric effects as described in paragraph 20.3.3.5.2.5).

Table 20-I. Subframe 1 Parameters

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range***	Units
Code on L2	2	1		discretes
Week No.	10	1		Week
L2 P data flag	1	1		discrete
SV accuracy	4			(see text)
SV health	6	1		discretes
T_{GD}	8*	2^{-31}		seconds
IODC	10			(see text)
t_{oc}	16	2^{4}	604,784	seconds
a_{f2}	8*	2^{-55}		sec/sec^2
a_{f1}	16*	2^{-43}		sec/sec
a_{f0}	22*	2^{-31}		seconds

* Parameters so indicated shall be two's complement, with the sign bit (+ or -) occupying the MSB;

** See Figure 20-1 for complete bit allocation in subframe;

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor.

20.3.3.3.3.1 User Algorithm for SV Clock Correction. The polynomial defined in the following allows the user to determine the effective SV PRN code phase offset referenced to the phase center of the SV antennas (Δt_{sv}) with respect to GPS system time (t) at the time of data transmission. The coefficients transmitted in subframe 1 describe the offset apparent to the two-frequency user for the interval of time in which the parameters are transmitted. This estimated correction accounts for the deterministic SV clock error characteristics of bias, drift and aging, as well as for the SV implementation characteristics of group delay bias and mean differential group delay. Since these coefficients do not include corrections for relativistic effects, the user's equipment must determine the requisite relativistic correction. Accordingly, the offset given below includes a term to perform this function.

The user shall correct the time received from the SV with the equation (in seconds)

$$t = t_{sv} - \Delta t_{sv} \qquad (1)$$

where

t = GPS system time (seconds),

t_{sv} = effective SV PRN code phase time at message transmission time (seconds),

Δt_{sv} = SV PRN code phase time offset (seconds).

The SV PRN code phase offset is given by

$$\Delta t_{sv} = a_{f0} + a_{f1}(t - t_{oc}) + a_{f2}(t - t_{oc})^2 + \Delta t_r \qquad (2)$$

where a_{f0}, a_{f1}, and a_{f2} are the polynomial coefficients given in subframe 1, t_{oc} is the clock data reference time in seconds (reference paragraph 20.3.4.5), and Δt_r is the relativistic correction term (seconds) which is given by

$$\Delta t_r = F\, e\, (A)^{1/2} \sin E_k.$$

The orbit parameters (e, A, E_k) used here are described in discussions of data contained in subframe 2 and 3, while F is a constant whose value is

$$F = \frac{-2(\mu)^{1/2}}{c^2} = -4.442807633(10)^{-10} \text{ sec/(meter)}^{1/2}.$$

where

$$\mu = 3.986005\text{x}10^{14} \frac{\text{meters}^3}{\text{second}^2} = \text{value of earths universal gravitational parameters}$$

$$c = 2.99792458\text{x}10^{8} \frac{\text{meters}}{\text{second}} = \text{speed of light}$$

Note that equations (1) and (2), as written, are coupled. While the coefficients a_{f0}, a_{f1}, and a_{f2} are generated by using GPS time as indicated in equation (2), sensitivity of t_{sv} to t is negligible. This negligible sensitivity will allow the user to approximate t by t_{sv} in equation (2). The value of t must account for beginning or end of week crossovers. That is, if the quantity $t-t_{oc}$ is greater than 302,400 seconds, subtract 604,800 seconds from t. If the quantity $t-t_{oc}$ is less than −302,400 seconds, add 604,800 seconds to t.

The control segment will utilize the following alternative by equivalent expression for the relativistic correction when estimating the NAV parameters:

$$\Delta t_r = -\frac{2\vec{R}\cdot\vec{V}}{c^2}$$

where

$\vec{R}$ is the instantaneous position vector of the SV,

$\vec{V}$ is the instantaneous velocity vector of the SV, and

c is the speed of light. (Reference paragraph 20.3.4.3).

It is immaterial whether the vectors $\vec{R}$ and $\vec{V}$ are expressed in earth-fixed, rotating coordinates or in earth-centered, inertial coordinates.

20.3.3.3.3.2 <u>L1 - L2 Correction</u>. The L1 and L2 correction term, T_{GD}, is calculated by the CS to account for the effect of SV group delay differential between L1 and L2 based on measurements made by the SV contractor during factory testing. This correction term is only for the benefit of "single-frequency" (L1 or L2) users; it is necessitated by the fact that the SV clock offset estimates reflected in the a_{f0} clock correction coefficient (see paragraph 20.3.3.3.3.1) are based on the effective PRN code phase as apparent with two frequency ionospheric corrections. Thus, the user who utilizes the L1 frequency only shall modify the code phase offset in accordance with paragraph 20.3.3.3.3.1 with the equation

$$(\Delta t_{sv})_{L1} = \Delta t_{sv} - T_{GD}$$

where T_{GD} is provided to the user as subframe 1 data. For the user who utilizes L2 only, the code phase modification is given by

$$(\Delta t_{sv})_{L2} = \Delta t_{sv} - \gamma T_{GD}$$

where, denoting the nominal center frequencies of L1 and L2 as f_{L1} and f_{L2} respectively,

$$\gamma = (f_{L1}/f_{L2})^2 = (1575.42/1227.6)^2 = (77/60)^2.$$

The value of T_{GD} is not equal to the mean SV group delay differential, but that delay multiplied by $1/(1 - \gamma)$. That is,

$$T_{GD} = \frac{1}{1-\gamma}(t_{L1} - t_{L2})$$

where, t_{Li} is the GPS time the i^{th} frequency signal is transmitted from the SV.

20.3.3.3.3.3 Ionospheric Correction. The two frequency (L1 and L2) user shall correct for the group delay due to ionospheric effects by applying the relationship:

$$PR = \frac{PR2 - \gamma PR1}{1 - \gamma}$$

where

PR = pseudorange corrected for ionospheric effects,

PR_i = pseudorange measured on the L-band channel indicated by the subscript,

while γ is as defined in paragraph 20.3.3.3.3.2. The clock correction coefficients are based on "two frequency" measurements and therefore account for the effects of mean differential delay in SV instrumentation.

20.3.3.3.3.4 Example Application of Correction Parameters. A typical system application of the correction parameters for a user receiver is shown in Figure 20-5. The ionospheric model referred to in Figure 20-5 is discussed in paragraph 20.3.3.5.2.5 in conjunction with the related data contained in page 18 of subframe 4.

20.3.3.4 Subframes 2 and 3. The contents of words three through ten of subframes 2 and 3 are defined below, followed by material pertinent to the use of the data.

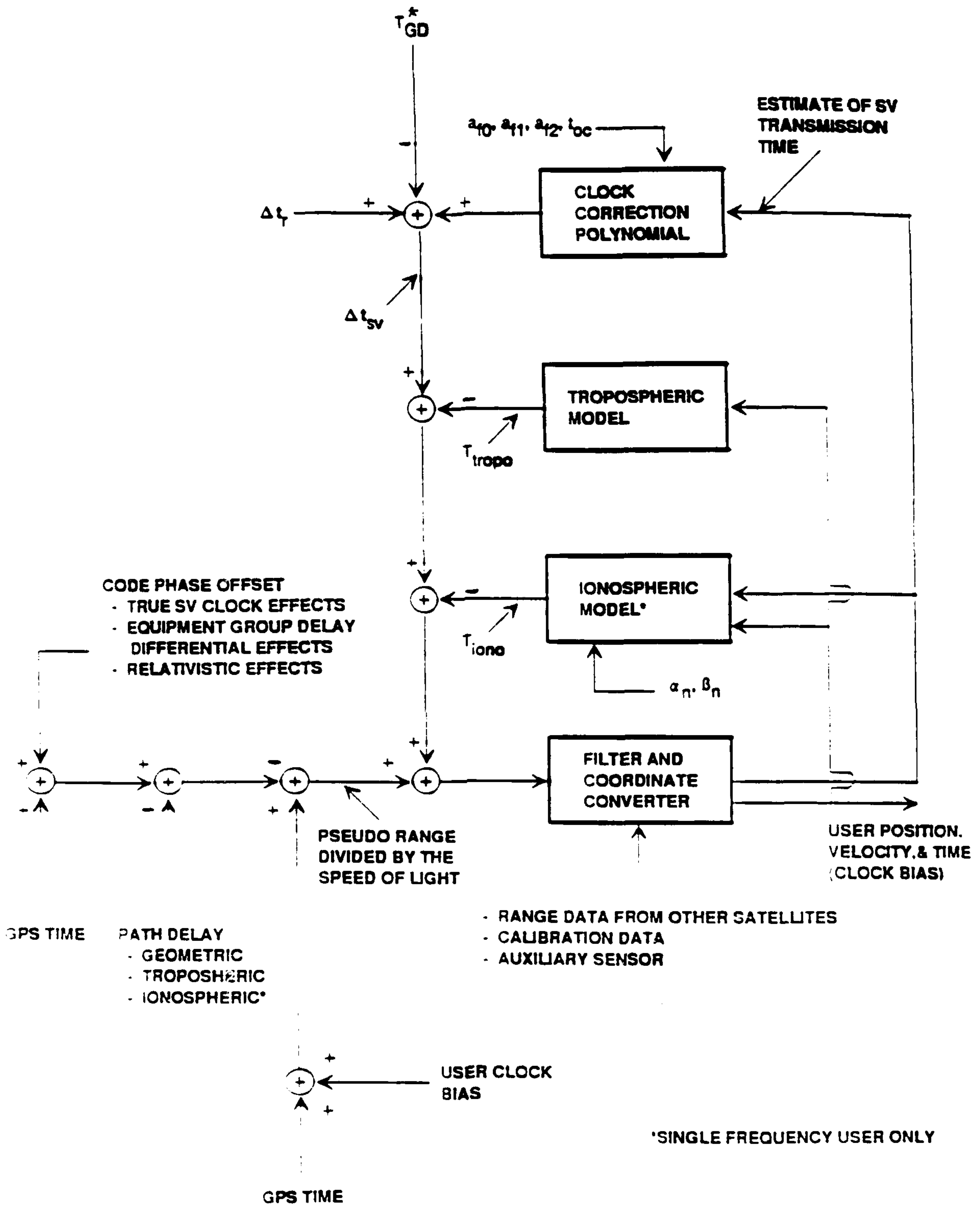

Figure 20-5. Sample Application of Correction Parameters

20.3.3.4.1 Content of Subframes 2 and 3. The third through tenth words of subframes 2 and 3 shall each contain six parity bits as their LSBs; in addition, two noninformation bearing bits shall be provided as bits 23 and 24 of word ten of each subframe for parity computation purposes. Bits 288 through 292 of subframe 2 shall be spares containing alternating ones and zeros with valid parity (reference paragraph 20.3.3.5.1.11). The remaining 375 bits of those two subframes shall contain the ephemeris representation parameters of the transmitting SV.

The ephemeris parameters describe the orbit during the curve fit intervals described in section 20.3.4. Table 20-II gives the definition of the orbital parameters using terminology typical of Keplerian orbital parameters; it shall be noted, however, that the transmitted parameter values are expressed for a coordinate system which allows the best trajectory fit in Earth fixed coordinates for each specific fit interval. The user shall not interpret intermediate coordinate values as pertaining to any conventional or stable coordinate system.

Table 20-II. Ephemeris Data Definitions

M_o	**Mean Anomaly at Reference Time**
Δn	**Mean Motion Difference from Computed Value**
e	**Eccentricity**
$(A)^{1/2}$	**Square Root of the Semi-Major Axis**
$(OMEGA)_o$	**Longitude of Ascending Node of Orbit Plane at Weekly Epoch**
i_o	**Inclination Angle at Reference Time**
ω	**Argument of Perigee**
OMEGADOT	**Rate of Right Ascension**
IDOT	**Rate of Inclination Angle**
C_{uc}	**Amplitude of the Cosine Harmonic Correction Term to the Argument of Latitude**
C_{us}	**Amplitude of the Sine Harmonic Correction Term to the Argument of Latitude**
C_{rc}	**Amplitude of the Cosine Harmonic Correction Term to the Orbit Radius**
C_{rs}	Amplitude of the Sine Harmonic Correction Term to the Orbit Radius
C_{ic}	Amplitude of the Cosine Harmonic Correction Term to the Angle of Inclination
C_{is}	Amplitude of the Sine Harmonic Correction Term to the Angle of Inclination
t_{oe}	Reference Time Ephemeris (reference paragraph 20.3.4.5)
IODE	Issue of Data (Ephemeris)

The issue of ephemeris data (IODE) term shall provide the user with a convenient means for detecting any change in the ephemeris representation parameters. The IODE is provided in both subframes 2 and 3 for the purpose of comparison with the 8 LSBs of the IODC term in subframe 1. Whenever these three terms do not match, a data set cutover has occurred and new data must be collected. The timing of the IODE and constraints on the IODC and IODE are defined in paragraph 20.3.4.4.

Any change in the subframe 2 and 3 data will be accomplished with a simultaneous change in both IODE words. The t_{oe} value, for at least the first data set transmitted by an SV after an upload, is different from that transmitted prior to the cutover.

A "fit interval" flag is provided in subframe 2 to indicate whether the ephemerides are based on a four-hour fit interval or a fit interval greater than four hours (reference paragraph 20.3.3.4.3.1).

20.3.3.4.2 Subframe 2 and 3 Parameter Characteristics. For each parameter contained in subframe 2 and 3, the number of bits, the scale factor of the LSB (which shall be the last bit received), the range, and the units shall be as specified in Table 20-III.

Table 20-III. Ephemeris Parameters
(Sheet 1 of 2)

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range***	Units
IODE	8			(see text)
C_{rs}	16*	2^{-5}		meters
Δn	16*	2^{-43}		semi-circles/sec
M_o	32*	2^{-31}		semi-circles
C_{uc}	16*	2^{-29}		radians
e	32	2^{-33}	0.03	dimensionless
C_{us}	16*	2^{-29}		radians
$(A)^{1/2}$	32	2^{-19}		$\text{meters}^{1/2}$
t_{oe}	16	2^4	604,784	seconds

* Parameters so indicated shall be two's complement, with the sign bit (+ or -) occupying the MSB;

** See Figure 20-1 for complete bit allocation in subframe;

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor.

Table 20-III. Ephemeris Parameters
(Sheet 2 of 2)

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range***	Units
C_{ic}	16*	2^{-29}		radians
$(OMEGA)_o$	32*	2^{-31}		semi-circles
C_{is}	16*	2^{-29}		radians
i_o	32*	2^{-31}		semi-circles
C_{rc}	16*	2^{-5}		meters
ω	32*	2^{-31}		semi-circles
OMEGADOT	24*	2^{-43}		semi-circles/sec
IDOT	14*	2^{-43}		semi-circles/sec

* Parameters so indicated shall be two's complement, with the sign bit (+ or -) occupying the MSB;
** See Figure 20-1 for complete bit allocation in subframe;
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor.

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20.3.3.4.3 User Algorithm for Ephemeris Determination. The user shall compute the earth fixed coordinates of position for the phase center of the SV's antennas utilizing a variation of the equations shown in Table 20-IV. Subframes 2 and 3 parameters are Keplerian in appearance; the values of these parameters, however, are obtained via a least squares curve fit of the predicted ephemeris for the phase center of the SV's antennas (time-position quadruples; t, x, y, z). Particulars concerning the periods of the curve fit, the resultant accuracy, and the applicable coordinate system are given in the following subparagraphs.

20.3.3.4.3.1 Curve Fit Intervals. Bit 17 in word 10 of subframe 2 is a "fit interval" flag which indicates the curve-fit interval used by the CS in determining the ephemeris parameters, as follows:

0 = 4 hours,

1 = greater than 4 hours.

The relationship of curve-fit interval to transmission time and the timing of the curve-fit intervals is covered in section 20.3.4.

20.3.3.4.3.2 (Deleted).

Table 20-IV. Elements of Coordinate Systems (sheet 1 of 3).

$\mu = 3.986005 \times 10^{14}$ meters^3/sec^2	WGS 84 value of the earth's universal gravitational parameter
$\dot{\Omega}_e = 7.2921151467 \times 10^{-5}$ rad/sec	WGS 84 value of the earth's rotation rate
$A = (\sqrt{A})^2$	Semi-major axis
$n_0 = \sqrt{\frac{\mu}{A^3}}$	Computed mean motion - rad/sec
$t_k = t - t_{oe}$*	Time from ephemeris reference epoch
$n = n_o + \Delta n$	Corrected mean motion
$M_k = M_o + nt_k$	Mean anomaly

* t is GPS system time at time of transmission, i.e., GPS time corrected for transit time (range/speed of light). Furthermore, t_k shall be the actual total time difference between the time t and the epoch time t_{oe}, and must account for beginning or end of week crossovers. That is, if t_k is greater than 302,400 seconds, subtract 604,800 seconds from t_k. If t_k is less than -302,400 seconds, add 604,800 seconds to t_k.

Table 20-IV. Elements of Coordinate Systems (sheet 2 of 3).

$M_k = E_k - e \sin E_k$	Kepler's equation for eccentric anomaly (may be solved by iteration) - radians
$\nu_k = \tan^{-1}\left\{\dfrac{\sin \nu_k}{\cos \nu_k}\right\} = \tan^{-1}\left\{\dfrac{\sqrt{1 - e^2} \sin E_k / (1 - e \cos E_k)}{(\cos E_k - e) / (1 - e \cos E_k)}\right\}$	True anomaly
$E_k = \cos^{-1}\left\{\dfrac{e + \cos \nu_k}{1 + e \cos \nu_k}\right\}$	Eccentric anomaly
$\Phi_k = \nu_k + \omega$	Argument of latitude

$$\left.\begin{array}{ll} \delta u_k = C_{us} \sin 2\Phi_k + C_{uc} \cos 2\Phi_k & \text{Argument of latitude correction} \\ \delta r_k = C_{rc} \cos 2\Phi_k + C_{rs} \sin 2\Phi_k & \text{Radius correction} \\ \delta i_k = C_{ic} \cos 2\Phi_k + C_{is} \sin 2\Phi_k & \text{Correction to inclination} \end{array}\right\} \text{Second harmonic perturbations}$$

$u_k = \Phi_k + \delta u_k$	Corrected argument of latitude
$r_k = A (1 - e \cos E_k) + \delta r_k$	Corrected radius
$i_k = i_o + \delta i_k + (IDOT)\ t_k$	Corrected inclination

Table 20-IV. Elements of Coordinate Systems (sheet 3 of 3).

$\left.\begin{aligned} x_k' &= r_k \cos u_k \\ y_k' &= r_k \sin u_k \end{aligned}\right\}$	Positions in orbital plane
$\Omega_k = \Omega_o + (\dot{\Omega} - \dot{\Omega}_e)\, t_k - \dot{\Omega}_e\, t_{oe}$	Corrected longitude of ascending node
$\left.\begin{aligned} x_k &= x_k' \cos \Omega_k - y_k' \cos i_k \sin \Omega_k \\ y_k &= x_k' \sin \Omega_k + y_k' \cos i_k \cos \Omega_k \\ z_k &= y_k' \sin i_k \end{aligned}\right\}$	Earth-fixed coordinates

20.3.3.4.3.3 Parameter Sensitivity. The sensitivity of the SV's antenna phase center position to small perturbations in most ephemeris parameters is extreme. The sensitivity of position to the parameters $(A)^{1/2}$, C_{rc} and C_{rs} is about one meter/meter. The sensitivity of position to the angular parameters is on the order of 10^8 meters/semicircle, and to the angular rate parameters is on the order of 10^{12} meters/semicircle/second. Because of this extreme sensitivity to angular perturbations, the value of π used in the curve fit is given here. π is a mathematical constant, the ratio of a circle's circumference to its diameter. Here π is taken as

$$\pi = 3.1415926535898 .$$

20.3.3.4.3.4 Coordinate System. The equations given in Table 20-IV provide the SV's antenna phase center position in the WGS 84 earth-centered earth-fixed reference frame defined as follows:

ORIGIN - Earth's center of mass*

Z-AXIS - Parallel to the direction of the CONVENTIONAL INTERNATIONAL ORIGIN (CIO) for polar motion, as defined by the BUREAU INTERNATIONAL DE L'HEURE (BIH) on the basis of the latitudes adopted for the BIH stations**

X-AXIS - Intersection of the WGS 84 reference meridian plane and the plane of the mean astronomic equator, the reference meridian being parallel to the zero meridian defined by the BUREAU INTERNATIONAL DE L'HEURE (BIH) on the basis of the longitudes adopted for the BIH stations***

Y-AXIS = Completes a right-handed earth-centered, earth-fixed orthogonal coordinate system, measured in the plane of the mean astronomic equator 90° east of the X-axis***

* Geometric center of WGS 84 ellipsoid

** Rotation axis of WGS 84 ellipsoid

*** X, Y axes of WGS 84 ellipsoid

20.3.3.4.3.5 Geometric Range. The user shall account for the effects due to earth rotation rate (reference Table 20-IV) during the time of signal propagation so as to evaluate the path delay in an inertially stable coordinate system. Specifically, if the user works in earth-fixed coordinates he should add $(-\dot{\Omega}_e y\Delta t, \dot{\Omega}_e x\Delta t, 0)$ to his position (x, y, z).

20.3.3.5 Subframes 4 and 5. Both subframe 4 and 5 are subcommutated 25 times each; the 25 versions of these subframes are referred to as pages 1 through 25 of each subframe. With the possible exception of "spare" pages and explicit repeats, each page contains different specific data in words three through ten. As shown in Figure 20-1, the pages of subframe 4 utilize six different formats, while those of subframe 5 use two. The content of words three through ten of each page is described below, followed by algorithms and material pertinent to the use of the data.

20.3.3.5.1 Content of Subframes 4 and 5. Words three through ten of each page contain six parity bits as their LSBs; in addition, two non-information bearing bits are provided as bits 23 and 24 of word ten in each page for parity computation purposes. The data contained in the remaining bits of words three through ten of the various pages in subframes 4 and 5 are described in the following subparagraphs.

A brief summary of the various data contained in each page of subframes 4 and 5 is as follows:

a. Subframe 4:

- Pages 1, 6, 11, 16, and 21: (reserved);

- Pages 2, 3, 4, 5, 7, 8, 9, and 10: almanac data for SV 25 through 32 respectively; these pages may be designated for other functions; the format and content for each page is defined by the SV ID of that page. In this case, the six-bit health word of page 25 is set to "6 ones" (Refer to 20.3.3.5.1.3) and the SV ID of the page will not have a value in the range of 25 through 32;

- Pages 12, 19, 20, 22, 23, and 24: (reserved);

- Pages 13, 14, and 15: spares;

- Page 17: special messages;

- Page 18: ionospheric and UTC data;

- Page 25: A-S flags/SV configurations for 32 SVs, plus SV health for SV 25 through 32.

b. Subframe 5:

- Pages 1 through 24: almanac data for SV 1 through 24;

- Page 25: SV health data for SV 1 through 24, the almanac reference time and the almanac reference week number.

20.3.3.5.1.1 Data ID and SV ID. The two MSBs of word three in each page shall contain the data ID which defines the applicable GPS NAV data structure. Data ID one (denoted by binary code 00) was utilized during Phase I of the GPS program and is no longer in use; data ID two (denoted by binary code 01) is described in this Appendix. Future data IDs will be defined as necessary.

As shown in Table 20-V, the data ID is utilized to provide one of two indications: (a) for those pages which are assigned to contain the almanac data of one specific SV, the data ID defines the data structure utilized by that SV whose almanac data are contained in that page; and (b) for all other pages, the data ID denotes the data structure of the transmitting SV.

The SV ID is given by bits three through eight of word three in each page as shown in Table 20-V. Specific IDs are reserved for each page of subframe 4 and 5; however, the SV ID of pages 2, 3, 4, 5, 7, 8, 9, and 10 of subframe 4 may change for each page to reflect the alternate contents for that page. The SV IDs are utilized in two different ways: (a) for those pages which contain the almanac data of a given SV, the SV ID is the same number that is assigned to the PRN code phase of that SV (reference Table 3-I), and (b) for all other pages the SV ID assigned in accordance with Table 20-V serves as the "page ID". IDs 1 through 32 are assigned to those pages which contain the almanac data of specific SVs (pages 1-24 of subframe 5 and pages 2-5 plus 7-10 of subframe 4). The "0" ID (binary all zeros) is assigned to indicate a dummy SV, while IDs 51 through 63 are utilized for pages containing other than almanac data of a specific SV. The remaining IDs (33 through 50) are unassigned.

Pages which contain identical data (for more frequent repetition) carry the same SV ID (e.g. in subframe 4, pages 1, 6, 11, 16, and 21 carry an ID of 57, while pages 12 and 24 are designated by an ID of 62).

Table 20-V. Data IDs and SV IDs in Subframes 4 and 5.

Page	Subframe 4		Subframe 5	
	Data ID	SV ID*	Data ID	SV ID*
1	Note(2)	57	Note(1)	1
2 Note(3)	Note(1)	25	Note(1)	2
3 Note(3)	Note(1)	26	Note(1)	3
4 Note(3)	Note(1)	27	Note(1)	4
5 Note(3)	Note(1)	28	Note(1)	5
6	Note(2)	57	Note(1)	6
7 Note(3)	Note(1)	29	Note(1)	7
8 Note(3)	Note(1)	30	Note(1)	8
9 Note(3)	Note(1)	31	Note(1)	9
10 Note(3)	Note(1)	32	Note(1)	10
11	Note(2)	57	Note(1)	11
12	Note(2)	62	Note(1)	12
13	Note(2)	52	Note(1)	13
14	Note(2)	53	Note(1)	14
15	Note(2)	54	Note(1)	15
16	Note(2)	57	Note(1)	16
17	Note(2)	55	Note(1)	17
18	Note(2)	56	Note(1)	18
19	Note(2)	58 Note(4)	Note(1)	19
20	Note(2)	59 Note(4)	Note(1)	20
21	Note(2)	57	Note(1)	21
22	Note(2)	60 Note(4)	Note(1)	22
23	Note(2)	61 Note(4)	Note(1)	23
24	Note(2)	62	Note(1)	24
25	Note(2)	63	Note(2)	51

* Use "0" to indicate "dummy" SV. When using "0" to indicate dummy SV, use the data ID of the transmitting SV.

Note 1: Data ID of that SV whose SV ID appears in that page.

Note 2: Data ID of transmitting SV.

Note 3: Pages 2, 3, 4, 5, 7, 8, 9, and 10 of subframe 4 may contain almanac data for SVs 25 through 32, respectively, or data for other functions as identified by a different SV ID from the value shown.

Note 4: SV ID may vary.

20.3.3.5.1.2 Almanac Data. Pages 1 through 24 of subframe 5, as well as pages 2 through 5 and 7 through 10 of subframe 4 contain the almanac data and a SV health word for up to 32 SVs (the health word is discussed in paragraph 20.3.3.5.1.3). The almanac data are a reduced-precision subset of the clock and ephemeris parameters. The data occupy all bits of words three through ten of each page except the eight MSBs of word three (data ID and SV ID), bits 17 through 24 of word five (SV health), and the 50 bits devoted to parity. The number of bits, the scale factor (LSB), the range, and the units of the almanac parameters are given in Table 20-VI. The algorithms and other material related to the use of the almanac data are given in paragraph 20.3.3.5.2.

The almanac message for any dummy SVs shall contain alternating ones and zeros with valid parity. For twelve or fewer SVs, almanacs may be repeated within the 25-cycle subcommutation limit. Whenever this option is exercised, the following constraints shall apply: (a) each page of subframes 4 and 5, which is assigned by Table 20-V to one of the active SVs in orbit, must contain the almanac data of that SV to which it is assigned by Table 20-V, (b) those almanac-type pages which remain unused per the above rule, shall then be reassigned to carry a duplicate set of almanac data for the active orbiting SV, (c) these page reassignments shall be in ascending order of page numbers (starting with subframe 5, followed by subframe 4) being used for SVs having an ascending order of SV IDs, and (d) each reassigned page must carry the SV ID of that SV whose almanac data it contains.

Table 20-VI. Almanac Parameters

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range***	Units
e	16	2^{-21}		dimensionless
t_{oa}	8	2^{12}	602,112	seconds
δ_i****	16 *	2^{-19}		semi circles
OMEGADOT	16 *	2^{-38}		semi circles/sec
$(A)^{1/2}$	24	2^{-11}		$\text{meters}^{1/2}$
$(\text{OMEGA})_0$	24 *	2^{-23}		semi circles
ω	24 *	2^{-23}		semi circles
M_0	24 *	2^{-23}		semi circles
a_{f0}	11 *	2^{-20}		seconds
a_{f1}	11 *	2^{-38}		sec/sec

* Parameters so indicated shall be two's complement, with the sign bit (+ or -) occupying the MSB;

** See Figure 20-1 for complete bit allocation in subframe;

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor;

**** Relative to i_0 = 0.30 semi-circles.

20.3.3.5.1.3 SV Health. Subframes 4 and 5 contain two types of SV health data: (a) each of the 32 pages which contain the clock/ephemeris related almanac data provide an eight-bit SV health status word regarding the SV whose almanac data they carry; and (b) the 25th pages of subframe 4 and of subframe 5 jointly contain six-bit health status data for up to 32 SVs.

The three MSBs of the eight-bit health words indicate health of the NAV data in accordance with the code given in Table 20-VII. The six-bit words provide a one-bit summary of the NAV data's health status in the MSB position in accordance with paragraph 20.3.3.3.1.4. The five LSBs of both the eight-bit and the six-bit health words provide the health status of the SVs signal components in accordance with the code given in Table 20-VIII. A special meaning is assigned, however, to the "6 ones" combination of the six-bit health words in the 25th pages of subframes 4 and 5: it indicates that "the SV which has that ID is not available and there may be no data regarding that SV in that page of subframes 4 or 5 that is assigned to normally contain the almanac data of that SV" (NOTE: (a) this special meaning applies to the 25th pages of subframes 4 and 5 only; and (b) there may be data regarding another SV in the almanac-page referred to above as defined in paragraph 20.3.3.5.1.1). The health indication shall be given relative to the "as designed" capabilities of each SV (as designated by the configuration code -- see paragraph 20.3.3.5.1.6). Accordingly, any SV which does not have a certain capability will be indicated as "healthy" if the lack of this capability is inherent in its design or it has been configured into a mode which is normal from a user standpoint and does not require that capability.

Table 20-VII. NAV Data Health Indications

Bit Position In Page			Indication
137	138	139	
0	0	0	ALL DATA OK
0	0	1	PARITY FAILURE -- some or all parity bad
0	1	0	TLM/HOW FORMAT PROBLEM -- any departure from standard format (e.g., preamble misplaced and/or incorrect, etc.), except for incorrect Z-count, as reported in HOW
0	1	1	Z-COUNT IN HOW BAD -- any problem with Z-count value not reflecting actual code phase
1	0	0	SUBFRAMES 1, 2, 3 -- one or more elements in words three through ten of one or more subframes are bad.
1	0	1	SUBFRAMES 4, 5 -- one or more elements in words three through ten of one or more subframes are bad.
1	1	0	ALL UPLOADED DATA BAD -- one or more elements in words three through ten of any one (or more) subframes are bad.
1	1	1	ALL DATA BAD -- TLM word and/or HOW and one or more elements in any one (or more) subframes are bad.

Table 20-VIII. Codes for Health of SV Signal Components

MSB LSB	Definition
0 0 0 0 0	All Signals OK
0 0 0 0 1	All Signals Weak*
0 0 0 1 0	All Signals Dead
0 0 0 1 1	All Signals Have No Data Modulation
0 0 1 0 0	L1 P Signal Weak
0 0 1 0 1	L1 P Signal Dead
0 0 1 1 0	L1 P Signal Has No Data Modulation
0 0 1 1 1	L2 P Signal Weak
0 1 0 0 0	L2 P Signal Dead
0 1 0 0 1	L2 P Signal Has No Data Modulation
0 1 0 1 0	L1 C Signal Weak
0 1 0 1 1	L1 C Signal Dead
0 1 1 0 0	L1 C Signal Has No Data Modulation
0 1 1 0 1	L2 C Signal Weak
0 1 1 1 0	L2 C Signal Dead
0 1 1 1 1	L2 C Signal Has No Data Modulation
1 0 0 0 0	L1 & L2 P Signal Weak
1 0 0 0 1	L1 & L2 P Signal Dead
1 0 0 1 0	L1 & L2 P Signal Has No Data Modulation
1 0 0 1 1	L1 & L2 C Signal Weak
1 0 1 0 0	L1 & L2 C Signal Dead
1 0 1 0 1	L1 & L2 C Signal Has No Data Modulation
1 0 1 1 0	L1 Signal Weak*
1 0 1 1 1	L1 Signal Dead
1 1 0 0 0	L1 Signal Has No Data Modulation
1 1 0 0 1	L2 Signal Weak*
1 1 0 1 0	L2 Signal Dead
1 1 0 1 1	L2 Signal Has No Data Modulation
1 1 1 0 0	SV Is Temporarily Out (Do not use this SV during current pass**)
1 1 1 0 1	SV Will Be Temporarily Out (Use with caution**)
1 1 1 1 0	Spare
1 1 1 1 1	More Than One Combination Would Be Required To Describe Anomalies (Except those marked by **)

* 3 to 6 dB below specified power level due to reduced power output, excess phase noise, SV attitude, etc.

Additional SV health data are given in subframe 1. The data given in subframes 1, 4, and 5 of the other SVs may differ from that shown in subframes 4 and/or 5 since the latter may be updated at a different time.

The eight-bit health status words shall occupy bits 17 through 24 of word five in those 32 pages which contain almanac data for individual SVs. The six-bit health status words shall occupy the 24 MSBs of words four through nine in page 25 of subframe 5 plus bits 19 through 24 of word 8, the 24 MSBs of word 9, and the 18 MSBs of word 10 in page 25 of subframe 4.

The predicted health data will be updated at the time of upload when a new almanac has been built by the CS. The transmitted health data may not correspond to the actual health of the transmitting SV or other SVs in the constellation.

20.3.3.5.1.4 (Reserved).

20.3.3.5.1.5 (Reserved).

20.3.3.5.1.6 Anti-Spoof (A-S) Flags and SV Configurations. Page 25 of subframe 4 shall contain a four-bit-long term for each of up to 32 SVs to indicate the A-S status and the configuration code of each SV. The MSB of each four-bit term shall be the A-S flag with a "1" indicating that A-S is ON. The three LSBs shall indicate the configuration of each SV using the following code:

Code	SV Configuration
000	"Block I" SV
001	"Block II" SV (A-S capability, plus flags for A-S and "alert" in HOW)

Additional codes will be assigned in the future, should the need arise.

These four-bit terms shall occupy bits 9 through 24 of word three, the 24 MSBs of words four through seven, and the 16 MSBs of word eight, all in page 25 of subframe 4.

20.3.3.5.1.7 Almanac Reference Week. Bits 17 through 24 of word three in page 25 of subframe 5 shall indicate the number of the week (WN_a) to which the almanac reference time (t_{oa}) is referenced (see paragraphs 20.3.3.5.1.2 and 20.3.3.5.2.2). The WN_a term consists of the eight LSBs of the full week number. Bits 9 through 16 of word three in page 25 of subframe 5 shall contain the value of t_{oa} which is referenced to this WN_a.

20.3.3.5.1.8 Universal Coordinated Time (UTC) Parameters. The 24 MSBs of words six through nine plus the eight MSBs of word ten in page 18 of subframe 4 shall contain the parameters related to correlating UTC time with GPS time. The bit length, scale factors, ranges, and units of these parameters are given in Table 20-IX. The related algorithms are described in paragraph 20.3.3.5.2.4.

20.3.3.5.1.9 Ionospheric Data The ionospheric parameters which allow the "L1 only" or "L2 only" user to utilize the ionospheric model (reference paragraph 20.3.3.5.2.5) for computation of the ionospheric delay are contained in page 18 of subframe 4. They occupy bits 9 through 24 of word three plus the 24 MSBs of words four and five. The bit lengths, scale factors, ranges, and units of these parameters are given in Table 20-X.

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Table 20-IX. UTC Parameters

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range ***	Units
A_0	32*	2^{-30}		seconds
A_1	24*	2^{-50}		sec/sec
Δt_{LS}	8*	1		seconds
t_{ot}	8	2^{12}	602,112	seconds
WN_t	8	1		weeks
WN_{LSF}	8	1		weeks
DN	8****	1	7	days
Δt_{LSF}	8*	1		seconds

* Parameters so indicated shall be two's complement, with the sign bit (+ or -) occupying the MSB;

** See Figure 20-1 for complete bit allocation in subframe;

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor.

**** Right justified.

Table 20-X. Ionospheric Parameters

Parameter	No. of Bits**	Scale Factor (LSB)	Effective Range ***	Units
α_0	8 *	2^{-30}		seconds
α_1	8 *	2^{-27}		sec. per semicircle
α_2	8 *	2^{-24}		sec. per semicircle^2
α_3	8 *	2^{-24}		sec. per semicircle^3
β_0	8 *	2^{11}		seconds
β_1	8 *	2^{14}		sec. per semicircle
β_2	8 *	2^{16}		sec. per semicircle^2
β_3	8 *	2^{16}		sec. per semicircle^3

* Parameters so indicated shall be two's complement, with the sign bit (+ or -) occupying the MSB;

** See Figure 20-1 for complete bit allocation in subframe;

*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor.

20.3.3.5.1.10 Special Messages. Page 17 of subframe 4 shall be reserved for special messages with the specific contents at the discretion of the Operating Command. It shall accommodate the transmission of 22 eight-bit ASCII characters. The requisite 176 bits shall occupy bits 9 through 24 of word three, the 24 MSBs of words four through nine, plus the 16 MSBs of word ten. The eight MSBs of word three shall contain the data ID and SV ID, while bits 17 through 22 of word ten shall be spares containing alternating ones and zeros. The remaining 50 bits of words three through ten are used for parity (six bits/word) and parity computation (two bits in word ten). The eight-bit ASCII characters shall be limited to the following set:

	ASCII	
Alphanumeric Character	Character	Code (Octal)
A - Z	A - Z	101 - 132
0 - 9	0 - 9	060 - 071
+	+	053
-	-	055
. (Decimal point)	.	056
' (Minute mark)	'	047
° (Degree sign)	°	370
/	/	057
Blank	Space	040
:	:	072
" (Second mark)	"	042

20.3.3.5.1.11 Spare Data Fields. All bits of words three through ten, except the 58 bits used for data ID, SV (page) ID, parity (six LSBs of each word) and parity computation (bits 23 and 24 of word ten) of pages 13, 14, and 15 of subframe 4 and those almanac pages assigned SV ID of zero are designated as spares. In addition, as shown in Table 20-XI, several smaller groups of spare bits exist in subframes 4 and 5. These spare bit positions of each word shall contain a pattern of alternation ones and zeros with valid word parity.

20.3.3.5.1.12 (Reserved).

20.3.3.5.2 Algorithms Related to Subframe 4 and 5 Data. The following algorithms shall apply when interpreting Almanac, Universal Coordinated Time, and Ionospheric data in the Navigation Message.

20.3.3.5.2.1 Almanac. The almanac is a subset of the clock and ephemeris data, with reduced precision. The user algorithm is essentially the same as the user algorithm used for computing the precise ephemeris from the subframe 1, 2, and 3 parameters (see Table 20-IV). The almanac content for one SV is given in Table 20-VI. A close inspection of Table 20-VI will reveal that a nominal inclination angle of 0.30 semicircles is implicit and that the parameter δ_i (correction to inclination) is transmitted, as opposed to the value being computed by the user. All other parameters appearing in the equations of Table 20-IV, but not included in the content of the almanac, are set to zero for SV position determination. In these respects, the application of the Table 20-IV equations differs between the almanac and the ephemeris computations.

Table 20-XI. Spare Bits in Subframes 4 and 5

Subframe	Page(s)	Word(s)	Spare Bit Positions in Word(s)
4	12, 19, 20, 22, 23, 24	9	9 - 24
4	1, 6, 11, 12, 16, 19, 20, 21, 22, 23, 24	10	1 - 22
4	17	10	17 - 22
4	18	10	9 - 22
4	25	8	17 - 18
4	25	10	19 - 22
5	25	10	1 - 22

NOTE: In addition, all bits of words three through ten in pages 13, 14, and 15 of subframe 4 (except the 58 bits used for data ID, SV (page) ID, parity and parity computation) are also designated as spares.

The user is cautioned that the sensitivity to small perturbation in the parameters is even greater for the almanac than for the ephemeris, with the sensitivity of the angular rate terms over the interval of applicability on the order of 10^{14} meters/(semicircle/second). An indication of the URE provided by a given almanac during each of the operational intervals is as follows:

Operational Interval	Almanac Ephemeris URE (estimated by analysis) 1 sigma (meters)
Normal	900*
Short-term Extended	900-3,600*
Long-term Extended	3600-300,000*

*URE values generally tend to degrade quadratically over time. Larger errors may be encountered during eclipse seasons and whenever a propulsive event has occurred.

20.3.3.5.2.2 Almanac Reference Time.

Normal and Short-term Operations. The almanac reference time, t_{oa}, is nominally the multiple of 2^{12} seconds truncated from 3.5 days after the first valid transmission time for this almanac data set (reference paragraph 20.3.4.5). The almanac is updated often enough to ensure that GPS time, t, shall differ from t_{oa} by less than 3.5 days during the transmission period. The time from epoch t_k shall be computed as described in Table 20-IV, except that t_{oe} shall be replaced with t_{oa}.

Long-term Extended Operations. During long-term extended operations or if the user wishes to extend the use time of the almanac beyond the time span that it is being transmitted, he must account for crossovers into time spans where these computations of t_k are not valid. This may be accomplished without time ambiguity by recognizing that the almanac reference time (t_{oa}) is referenced to the almanac reference week (WN_a) both of which are given in word three of page 25 of subframe 5 (see paragraph 20.3.3.5.1.7).

The CS shall ensure that all t_{oa} values in subframes 4 and 5 are the same for a given almanac data set and that they differ for successive data sets which contain changes in almanac parameters or SV health. Note that cutover to a new upload may occur between the almanac pages of interest and page 25 of subframe 5 (reference paragraph 20.3.4.1), and thus there may be a temporary inconsistency between t_{oa}, in the almanac page of interest, and in word 3 of page 25 of subframe 5. The t_{oa} mismatch signifies that this WN_a may not apply to the almanac of interest and that the user must not apply almanac data until he obtains these pages with identical values of t_{oa}.

20.3.3.5.2.3 Almanac Time Parameters The almanac time parameters shall consist of an 11-bit constant term (a_{f0}) and an 11-bit first order term (a_{f1}). The applicable first order polynomial, which shall provide time to within

2 microseconds of GPS time (t) during the interval of applicability, is given by

$$t = t_{sv} - \Delta t_{sv}$$

where

t = GPS system time (seconds),

t_{sv} = effective SV PRN code phase time at message transmission time (seconds),

Δt_{sv} = SV PRN code phase time offset (seconds).

The SV PRN code phase offset is given by

$$\Delta t_{sv} = a_{f0} + a_{f1} t_k$$

where the computation of t_k is described in paragraph 20.3.3.5.2.2, and the polynomial coefficients a_{f0} and a_{f1} are given in the almanac. Since the periodic relativistic effect is less than 25 meters, it need not be included in the time scale used for almanac evaluation. Over the span of applicability, it is expected that the almanac time parameters will provide a statistical URE component of less than 135 meters, one sigma. This is partially due to the fact that the error caused by the truncation of a_{f0} and a_{f1}, may be as large as 150 meters plus 50 meters/day relative to the t_{oa} reference time.

During extended operations (short-term and long-term) the almanac time parameter may not provide the specified time accuracy or URE component.

20.3.3.5.2.4 Universal Coordinated Time (UTC). Page 18 of subframe 4 includes: (1) the parameters needed to relate GPS time to UTC, and (2) notice to the user regarding the scheduled future or recent past (relative to NAV message upload) value of the delta time due to leap seconds (Δt_{LSF}), together with the week number (WN_{LSF}) and the day number (DN) at the end of which the leap second becomes effective. "Day one" is the first day relative to the end/start of week and the WN_{LSF} value consists of the eight LSBs of the full week number. The user must account for the truncated nature of this parameter as well as truncation of WN, WN_t, and W_{LSF} due to rollover of the full week number (see paragraph 3.3.4(b)). The CS shall manage these parameters such that the absolute value of the difference between the untruncated WN and WN_{LSF} values shall not exceed 127.

Depending upon the relationship of the effectivity date to the user's current GPS time, the following three different UTC/GPS-time relationships exist:

a. Whenever the effectivity time indicated by the WN_{LSF} and the DN values is not in the past (relative to the user's present time), <u>and</u> the user's present time does not fall in the timespan which starts at DN + 3/4 and ends at DN + 5/4, the UTC/GPS-time relationship is given by

$$t_{UTC} = (t_E - \Delta t_{UTC}) \quad [\text{Modulo } 86400 \text{ seconds}]$$

where t_{UTC} is in seconds and

Δt_{UTC} = $\Delta t_{LS} + A_0 + A_1 (t_E - t_{0t} + 604800 (WN - WN_t))$, seconds;

t_E = GPS time as estimated by the user on the basis of correcting t_{SV} for factors described in paragraph 20.3.3.3.3 as well as for ionospheric and SA (dither) effects;

Δt_{LS} = delta time due to leap seconds;

A_0 and A_1 = constant and first order terms of polynomial;

t_{0t} = reference time for UTC data (reference 20.3.4.5);

WN - current week number (derived from subframe 1);

WN_t - UTC reference week number.

The estimated GPS time (t_E) shall be in seconds relative to end/start of week. The reference time for UTC data (t_{ot}) shall be referenced to the start of that week whose number (WN_t) is given in word eight of page 18 in subframe 4. The WN_t value consists of the eight LSBs of the full week number. The user must account for the truncated nature of this parameter as well as truncation of WN, WN_t and W_{LSF} due to rollover of the full week number (see paragraph 3.3.4(b)). The CS shall manage these parameters such to that the absolute value of the difference between the untruncated WN and WN_t values shall not exceed 127. The absolute value of the difference between the untruncated WN and WN_t values shall not exceed 127.

b. Whenever the user's current time falls within the timespan of DN + 3/4 to DN + 5/4, proper accommodation of the leap second event with a possible week number transition is provided by the following expression for UTC:

$$t_{UTC} = W[\text{Modulo } (86400 + \Delta t_{LSF} - \Delta t_{LS})], \text{ seconds;}$$

where

$$W = (t_E - \Delta t_{UTC} - 43200)[\text{Modulo } 86400] + 43200, \text{ seconds;}$$

and the definition of Δt_{UTC} (as given in "a" above) applies throughout the transition period. Note that when a leap second is added, unconventional time values of the form 23: 59: 60.xxx are encountered. Some user equipment may be designed to approximate UTC by decrementing the running count of time within several seconds after the event, thereby promptly returning to a proper time indication. Whenever a leap second event is encountered, the user equipment must consistently implement carries or borrows into any year/week/day counts.

c. Whenever the effectivity time of the leap second event, as indicated by the WN_{LSF} and DN values, is in the "past" (relative to the user's current time), the relationship previously given for t_{UTC} in "a" above is valid except that the value of Δt_{LSF} is substituted for Δt_{LS}. The update of UTC parameters are coordinated so as to maintain the continuity of the t_{UTC} time scale.

20.3.3.5.2.5 Ionospheric Model. The "two frequency" (L1 and L2) user shall correct the time received from the SV for ionospheric effect by utilizing the time delay differential between L1 and L2 (reference paragraph 20.3.3.3.3.3). The "one frequency" user, however, may use the model given in Figure 20-6 to make this correction. It is estimated that the use of this model will provide at least a 50 percent reduction in the single - frequency user's RMS error due to ionospheric propagation effects. During extended operations the use of this model will yield unpredictable results.

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The ionospheric correction model is given by

$$T_{iono} = \begin{cases} F * \left[5.0 * 10^{-9} + (AMP)\left(1 - \frac{x^2}{2} + \frac{x^4}{24}\right)\right], & |x| < 1.57 \\ F * (5.0 * 10^{-9}), & |x| \geq 1.57 \end{cases} \text{(sec)}$$

where

T_{iono} is referred to the L1 frequency; if the user is operating on the L2 frequency, the correction term must be multiplied by γ (reference paragraph 20.3.3.3.3.2),

$$AMP = \begin{cases} \sum_{n=0}^{3} \alpha_n \phi_m^n, & AMP \geq 0 \\ \text{if } AMP < 0, & AMP = 0 \end{cases} \text{(sec)}$$

$$x = \frac{2\pi(t - 50400)}{PER}, \text{(radians)}$$

$$PER = \begin{cases} \sum_{n=0}^{3} \beta_n \phi_m^n, & PER \geq 72000 \\ \text{if } PER < 72000, & PER = 72000 \end{cases} \text{(sec)}$$

$F = 1.0 + 16.0 [0.53 - E]^3$, and

α_n and β_n are the satellite transmitted data words with n = 0, 1, 2, and 3.

Figure 20-6. Ionospheric Model (Sheet 1 of 4)

Other equations that must be solved are

$$\phi_m = \phi_i + 0.064 \cos (\lambda_i - 1.617) \quad \text{(semi-circles)},$$

$$\lambda_i = \lambda_u + \frac{\psi \sin A}{\cos \phi_i} \quad \text{(semi-circles)},$$

$$\phi_i = \left\{ \begin{array}{l} \phi_u + \psi \cos A \text{ (semi-circles)}, \; |\phi_i| \leq 0.416 \\ \text{if } \phi_i > 0.416, \text{ then } \phi_i = +0.416 \\ \text{if } \phi_i < -0.416, \text{ then } \phi_i = -0.416 \end{array} \right\} \text{(semi-circles)},$$

$$\psi = \frac{0.0137}{E + 0.11} - 0.022 \quad \text{(semi-circles)},$$

$$t = 4.32 * 10^4 \lambda_i + \text{GPS time} \quad \text{(sec)}$$

where

$0 \leq t < 86400$, therefore: if $t \geq 86400$ seconds, subtract 86400 seconds;
if $t < 0$ seconds, add 86400 seconds.

Figure 20-6. Ionospheric Model (Sheet 2 of 4)

The terms used in computation of ionospheric delay are as follows:

- Satellite Transmitted Terms

α_n	the coefficients of a cubic equation representing the amplitude of the vertical delay (4 coefficients - 8 bits each)
β_n	the coefficients of a cubic equation representing the period of the model (4 coefficients - 8 bits each)

- Receiver Generated Terms

E	elevation angle between the user and satellite (semi-circles)
A	azimuth angle between the user and satellite, measured clockwise positive from the true North (semi-circles)
ϕ_u	user geodetic latitude (semi-circles) WGS-84
λ_u	user geodetic longitude (semi-circles) WGS-84
GPS time	receiver computed system time

- Computed Terms

x	phase (radians)
F	obliquity factor (dimensionless)

Figure 20-6. Ionospheric Model (Sheet 3 of 4)

t	local time (sec)
ϕ_m	geomagnetic latitude of the earth projection of the ionospheric intersection point (mean ionospheric height assumed 350 km) (semi-circles)
λ_i	geodetic longitude of the earth projection of the ionospheric intersection point (semi-circles)
ϕ_i	geodetic latitude of the earth projection of the ionospheric intersection point (semi-circles)
ψ	earth's central angle between user position and earth projection of ionospheric intersection point (semi-circles)

Figure 20-6. Ionospheric Model (Sheet 4 of 4)

20.3.3.5.2.6 (Reserved).

20.3.4 Timing Relationships. The following conventions shall apply.

20.3.4.1 Paging and Cutovers. At end/start of week (a) the cyclic paging of subframes 1 through 5 shall restart with subframe 1 regardless of which subframe was last transmitted prior to end/start of week, and (b) the cycling of the 25 pages of subframes 4 and 5 shall restart with page 1 of each of the subframes, regardless of which page was the last to be transmitted prior to the end/start of week. It shall be a CS responsibility to ensure that all upload and page cutovers shall occur on frame boundaries (i.e., Modulo 30 seconds relative to end/start of week); accordingly, new data in subframes 4 and 5 may start to be transmitted with any of the 25 pages of these subframes.

20.3.4.2 SV Time vs. GPS Time. In controlling the SVs and uploading of data, the CS shall allow for the following timing relationships:

a. Each SV operates on its own SV time;

b. All time-related data in the TLM word and the HOW shall be in SV-time;

c. All other data in the NAV message shall be relative to GPS time;

d. The acts of transmitting the NAV message, shall be executed by the SV on SV time.

20.3.4.3 Speed of Light. The speed of light used by the CS for generating the data described in the above paragraphs is

$$c = 2.99792458 \times 10^8 \text{ meters per second}$$

which is the official WGS-84 speed of light. The user shall use the same value for the speed of light in his computations.

20.3.4.4 Data Sets. The IODE is an 8 bit number equal to the 8 LSBs of the 10 bit IODC of the same data set. The following rules govern the transmission of IODC and IODE values in different data sets. (1) The transmitted IODC will be different from any value transmitted by the SV during the preceding seven days. (2) The transmitted IODE will be different from any value transmitted by the SV during the preceding six hours. (3) For Block I SVs, the IODCs shall be any numbers in the range 0 to 1023 excluding those values of IODCs that correspond to IODEs values in the range 240 to 255. For Block II SVs, the range of IODC will be as given in Table 20-XIA.

Cutovers to new data sets will occur only on hour boundaries except for the first data set of a new upload. The first data set may be cut-in (reference paragraph 20.3.4.1) at any time during the hour and therefore may be transmitted by the SV for less than one hour. During short-term operations, cutover to 4-hour sets and subsequent cutovers to succeeding 4-hour data sets will always occur modulo 4 hours relative to end/start of week. Cutover from 4-hour data sets to 6-hour data sets shall occur modulo 12 hours relative to end/start of week. Cutover from 12-hour data sets to 24 hour data sets shall occur modulo 24 hours relative to end/start of week. Cutover from a data set transmitted 24 hours or more occurs on a modulo 24-hour boundary relative to end/start of week.

The start of the transmission interval for each data set corresponds to the beginning of the curve fit interval for the data set. Each data set remains valid for the duration of its curve fit interval.

Table 20-XIA. IODC Values and Data Set Lengths for Block II SVs.

Days Spanned	Transmission Interval (hours)	Curve Fit Interval (hours)	IODC Range (Note 1)
1	2	4	(Note 2)
2-14	4	6	(Note 2)
15-16	6	8	240-247
17-20	12	14	248-255, 496 (Note 3)
21-27	24	26	497-503
28-41	48	50	504-510
42-59	72	74	511, 752-756
60-87	96	98	757-763
88-122	120	122	764-767, 1008-1010
123-182	144	146	1011-1020

Note 1: For transmission intervals of 6 hours or greater, the IODC values shown will be transmitted in increasing order.

Note 2: IODC values for blocks with 2- or 4-hour transmission intervals (at least the first 14 days after upload) shall be any numbers in the range 0 to 1023 excluding those values of IODC that correspond to IODE values in the range 240-255, subject to the constraints on retransmission given in paragraph 20.3.4.4.

Note 3: The ninth 12-hour data set may not be transmitted.

Normal Operations. For Block I SVs, the subframe 1, 2, and 3 data sets are transmitted by the SV for periods of one hour. The corresponding curve-fit interval is four hours.

For Block II SVs the subframe 1, 2, and 3 data sets are transmitted by the SV for periods of two hours. The corresponding curve-fit interval is four hours.

Short-term and Long-term Extended Operations. For the first 2 to 3 days of short-term operations, Block I SVs will transmit data sets for periods of four hours. (Block I SVs can only store a total of 3-4 days of uploaded data.) The corresponding curve fit intervals are six hours. For Block II SVs, the transmission intervals and curve-fit intervals with the applicable IODC ranges are given in Table 20-XIA.

20.3.4.5 Reference Times. Many of the parameters which describe the SV state vary with true time, and must therefore be expressed as time functions with coefficients provided by the Navigation Message so as to be evaluatable by the user equipment. These include the following parameters as functions of GPS time:

a. SV time,
b. Mean anomaly,
c. Longitude of ascending node,
d. UTC,
e. Inclination.

Each of these parameters is formulated as a polynomial in time. The specific time scale of expansion can be arbitrary. Due to the short data field lengths available in the Navigation Message format, the nominal epoch of the polynomial is chosen near the midpoint of the expansion range so that quantization error is small. This results in time epoch values which can be different for each data set. Time epochs contained in the Navigation Message and the algorithms which utilize them are related as follows:

Epoch	Application Algorithm Reference
t_{oc}	20.3.3.3.3.1
t_{oe}	20.3.3.4.3
t_{oa}	20.3.3.5.2.2 and 20.3.3.5.2.3
t_{ot}	20.3.3.5.2.4

For Block I SVs, the following describes the nominal selection, which will be expressed Modulo 604,800 seconds in the Navigation Message:

t_{oc} , t_{oe} ≈ 2 hours after the first valid transmission time for 4-hour fit interval data sets, and 3 hours after the start of transmission for 6-hour fit interval data sets.

t_{oa} , t_{ot} ≈ 3.5 days after the first valid transmission time.

For Block II SVs, Table 20-XIB describes the nominal selection, which will be expressed Modulo 604,800 seconds in the Navigation Message.

The coefficients of expansion are obviously dependent upon the choice of epoch, and thus the epoch time and expansion coefficients must be treated as an inseparable parameter set. Note that a user applying current navigation data will normally be working with negative values of $(t-t_{oc})$ and $(t-t_{oe})$ in evaluating the expansions.

The CS will introduce small deviations from the nominal if necessary to preclude possible data set transition ambiguity when a new upload is cut over for transmission. A change of reference time is used to indicate a change of values in the data set.

Table 20-XIB. Reference Times for Block II SVs.

Fit Interval (hours)	Transmission Interval (hours)	Hours After First Valid Transmission Time			
		t_{oc} (clock)	t_{oe} (ephemeris)	t_{oa} (almanac)	t_{ot} (UTC)
4	2	2	2		
6	4	3	3		
8	6	4	4		
14	12	7	7		
26	24	13	13		
50	48	25	25		
74	72	37	37		
98	96	49	49		
122	120	61	61		
146	144	73	73		
144 (6 days)	144			84	84
144 (6 days)	4080			84	84

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20.3.5 Data Frame Parity. The data signal shall contain parity coding according to the following conventions.

20.3.5.1 SV/CS Parity Algorithm. This algorithm links 30-bit words within and across subframes of ten words, using the (32.26) Hamming Code described in Table 20-XII.

20.3.5.2 User Parity Algorithm. As far as the user is concerned, several options are available for performing data decoding and error detection. Figure 20-7 presents an example flow chart that defines one way of recovering data (d_n) and checking parity. The parity bit D^*_{30} is used for recovering raw data. The parity bits D^*_{29} and D^*_{30}, along with the recovered raw data (d_n) are modulo-2 added in accordance with the equations appearing in Table 20-XII for D_{25} . . . D_{30}, which provide computed parity to compare with transmitted parity D_{25} . . . D_{30}.

Table 20-XII. Parity Encoding Equations

$$D_1 = d_1 \oplus D_{30}^*$$

$$D_2 = d_2 \oplus D_{30}^*$$

$$D_3 = d_3 \oplus D_{30}^*$$

$$\bullet \qquad \bullet$$

$$\bullet \qquad \bullet$$

$$\bullet \qquad \bullet$$

$$D_{24} = d_{24} \oplus D_{30}^*$$

$$D_{25} = D_{29}^* \oplus d_1 \oplus d_2 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_{10} \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{17} \oplus d_{18} \oplus d_{20} \oplus d_{23}$$

$$D_{26} = D_{30}^* \oplus d_2 \oplus d_3 \oplus d_4 \oplus d_6 \oplus d_7 \oplus d_{11} \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{18} \oplus d_{19} \oplus d_{21} \oplus d_{24}$$

$$D_{27} = D_{29}^* \oplus d_1 \oplus d_3 \oplus d_4 \oplus d_5 \oplus d_7 \oplus d_8 \oplus d_{12} \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{19} \oplus d_{20} \oplus d_{22}$$

$$D_{28} = D_{30}^* \oplus d_2 \oplus d_4 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{13} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{20} \oplus d_{21} \oplus d_{23}$$

$$D_{29} = D_{30}^* \oplus d_1 \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_7 \oplus d_9 \oplus d_{10} \oplus d_{14} \oplus d_{15} \oplus d_{16} \oplus d_{17} \oplus d_{18} \oplus d_{21} \oplus d_{22} \oplus d_{24}$$

$$D_{30} = D_{29}^* \oplus d_3 \oplus d_5 \oplus d_6 \oplus d_8 \oplus d_9 \oplus d_{10} \oplus d_{11} \oplus d_{13} \oplus d_{15} \oplus d_{19} \oplus d_{22} \oplus d_{23} \oplus d_{24}$$

where

$d_1, d_2, \ldots, d_{24}$ are the source data bits;
the symbol (*) is used to identify the last 2 bits of the previous word of the subframe;
$D_{25}, \ldots, D_{30}$ are the computed parity bits;
$D_1, D_2, D_3, \ldots, D_{29}, D_{30}$ are the bits transmitted by the SV; and
$\oplus$ is the "Modulo-2" or "Exclusive-Or" operation.

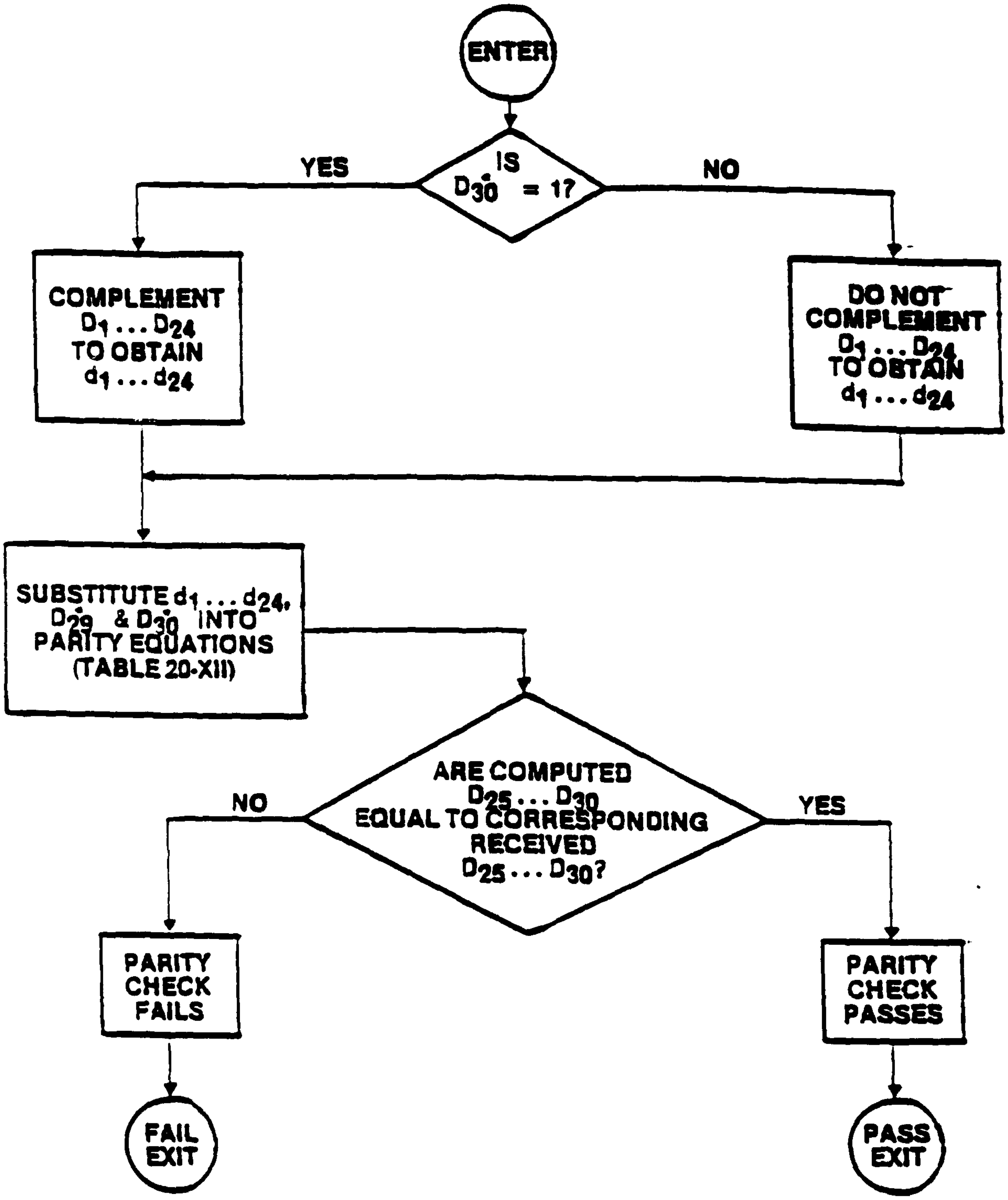

Figure 20-7. Example Flow Chart for User Implementation of Parity Algorithm